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PROCESS FOR WORKPIECE TREATMENT IN A

VACUUM ATOMSPHERE AND VACUUM TREATMENT SYSTEM

[Verfahren zur Werkstückbehandlung in einer

Vakuumatmosphäre und Vakuumbehandlungsanlage]

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This invention relates to a process according to the preambles of Claims 1 or 2.

The invention can be employed in all PVD (physical vapor deposition) processes, reactive PVD processes as well as all plasma-supported CVD (chemical wafer deposition) processes and in other processes provided the mentioned conditions prevail. Such processes, in particular, are reactive or nonreactive sputtering, where workpieces are sputter-etched or sputter-coated and in the process are applied upon bias, upon a reference potential or [are] operated in a potential-floating manner.

This invention further, in particular, relates to ion-plating processes, both reactive or nonreactive, and to vaporization processes, that is to say, electron beam vaporization processes, arc vaporization processes, vaporization processes with crucible heating, all of which can also be used in conjunction with ion plating, in other words - repeating this - it generally relates to all vacuum treatment processes where the mentioned whole or partial coverage of a conducting surface occurs with nonconducting or poorly conducting material, be this due to the specific treatment method or be this due to a

[1] Numbers in the margin indicate pagination in the foreign text.

situation when such coverages are present already prior to the start of the process upon used conducting parts such as in surface oxidation of metal parts.

Whenever the prescribed conditions, that is to say, whole or partial coverage, and in the vacuum atmosphere, charge carriers, are met, in other words, also, for example, in case of thermal CVD processes where charge carriers are introduced, for example, for surface activation in the form of ions or electrons, as electron beam or also as ion beam, then one encounters problems by virtue of the fact that upon the coating with nonconducting or poorly conducting material, hereinafter called "insulation coating," especially when electromagnetic force fields are applied in the vacuum atmosphere and/or are generated by nonhomogeneous charge distributions, one uses or can use an additional coating with electrical charge carriers, which hereafter will be called "charge carrier coverage." This results in the electrostatic charging of the insulation coating until that charge is discharged in an uncontrolled manner.

Basically, the problem was so far solved in connection with electrical power supply of such insulation-covered surfaces that, as power source, one applied either an AC signal generator or a DC signal generator and an AC signal generator. In spite of the stochastic interference discharge that appears only briefly in negative terms, looking at it over the long treatment

times, it was instead decided during the entire treatment process permanently to connect an AC generator, be it a pulse generator, an RF generator, etc.

The invention at hand starts with the following realization: the fact that the mentioned phenomena appear only relatively briefly during the treatment processes in a negative fashion that would then not justify the expensive supply of an AC generator when it is possible to counter the mentioned phenomena in a quasi-time-selective manner and, in that case, until necessary in a technical signal manner, such as this is necessary in the first place in order to carry out a considered treatment method with intended result.

In the case of electric power supply for the surfaces mentioned, this problem is solved basically by the procedure according to the characterizing part of Claim 1, in other words: The output signal of a direct-current signal generator is applied to the mentioned surfaces and, during treatment, one applies an additional signal, deviating from the mentioned output signal, upon the surfaces in a specifically targeted manner as often and/or as long as required by the mentioned charge covering conditions and, in the process, averaged over the treatment time, the mentioned output signal is left applied considerably longer than the additional signal.

In that way, in addition to the direct-current signal generator, one can activate other signal generators for the additional signal in a specifically targeted manner only so long as necessary and one can then accordingly also dimension it properly, such as this is required by the charge coverage conditions as determined, for example, in prior experiments. On the other hand, the charge coverage conditions can be acquired in terms of "real time" and can be dimensioned in accordance with the use of the additional signal.

By virtue of the first aspect, that is, the solution according to Claim 1, one can make sure that a "dangerous" charge coverage will not be generated in spite of the electrical direct-current generator power supply.

The second aspect of the invention consists in the following: to cancel out the electrostatic effect of an existing, especially also - as in the case of ion plating - of a charge bridge that is desired as an inherent part of the process and, in the course of further development, mostly to retain the coverage. This applies independently of the fact as to whether the considered surfaces are supplied electrically externally and also always [sic]. This is achieved when one proceeds according to Claim 2.

A very typical example where, in an inherently process-connected manner, one does want a charge coverage, the mentioned

ion plating, where one is supposed to deposit ions out of the vacuum atmosphere upon a workpiece surface in order to build up a desired layer. The coverage ions are driven upon the surface to be covered by electrical fields in the vacuum atmosphere. Due to this process that is inherent in ion plating, it was so far not at all possible to apply layers of nonconducting or poorly conducting material by means of ion plating or on nonconducting or poorly conducting surfaces of workpieces by ion plating and also to remove layers consisting of conducting materials. Here is why: It was no longer possible to get the coverages that are built up and that consist of nonconducting or poorly conducting material to generate a field in the vacuum atmosphere quickly or if this is not possible from the very beginning in the case of already existing nonconducting or poorly conducting workpiece surfaces. /3

This means that ion plating is a process where:

a) ions are to be applied on a workpiece through an externally applied monodirectional electrical field in the vacuum atmosphere and where there is thus a need for an external electrical potential application upon the workpiece;

b) the coverage with ions may not be built up because, otherwise, the process objective is not attained, [that is], efficient layer formation.

By combining both of the invention-based solution aspects according to Claim 3, one can thus in the first place make all possible certain processes such as especially the previously mentioned ion plating process under the previously mentioned insulation coverage conditions.

As mentioned, the insulation coverages can be coverages that are formed other than through treatment, that is to say, for example, uncontrolled reacting of dirt contamination gases that remain in the treatment atmosphere, whose reaction products are deposited on surfaces that are exposed to the treatment atmosphere or can be formed beforehand by dirt contamination layers [on] conducting objects, such as through oxide layers on metals. But they can also be formed as an inherent part of the process in the case of coating processes of nonconducting or poorly conducting material and/or during coating with layers of nonconducting or poorly conducting materials where the charge coverage then builds up the insulation coverage.

Looking at treatment processes where, due to the requirements of the process, no poorly conducting or nonconducting materials are involved, the widespread practice is to work stretches between two metallic surfaces in the vacuum atmosphere with direct-current signals, for example, to maintain a plasma discharge or for bias application on workpieces, screens, electrodes, etc.

Although, as mentioned before, no poorly conducting or nonconducting materials are involved in these processes, it is also known that, for example, the dirt contamination layers built up on metallic bodies in a normal atmosphere such as, for example, in particular, an oxide layer. When such surfaces are then involved in the process, one gets during the initial phases of such processes, as is known, the previously mentioned stochastic discharge phenomena which, however, are accepted as part of the bargain because providing AC generators would not be justified, looking at it from the angle of the effort involved only to eliminate these phenomena during the initial phase of a treatment process. But connected sources in generators and other system subassemblies are stressed massively electrically and/or mechanically/thermally and must be appropriately secured or dimensioned or they must frequently be replaced.

It is especially this problem that is solved by the invention from the initially mentioned first aspect according to Claim 1 without any need for any expensive AC generators.

Summarizing, looking at it from the first aspect, the invention solves the problem of also using direct-current generators when one employed as so far combined DC and AC generators each time for sustained operation based on the required design.

Looking at the second aspect, the invention solves the problem of building up charge carrier coverages on insulation coverages or those that by themselves build up an insulation coverage without essentially interfering with the material coverage corresponding to the charge coverage [in order thus] to neutralize them electrically.

US-PS-4 692 230 discloses a process where, as part of a cathode atomization process starting from magnetron target objects, both electrically conducting and insulating target object materials are alternately atomized. Using the materials that are atomized, one coats a workpiece. Characteristically, when conducting target object materials are atomized, they are atomized in a section that is operated by direct current. When the insulating target object materials are atomized, this is done with monopolar pulse groups of an AC generator. These operating modes alternate.

US-PS-4 693 805 describes a process for atomization coating, starting with dielectric target object or for reactive atomization coating, for atomization etching, etc., that is to say, treatment processes where, in the initially mentioned context, inherently process connected, nonconducting or poorly conducting materials are involved and where insulation coatings occur.

To master the electrostatic charging - charge coatings - of such insulation coatings in a first segment between a target object cathode and an anode, one provides an additional auxiliary segment between the mentioned target object and a third electrode.

The two segments, whereupon the target object forms the common electrode, are - starting from one direct-current power supply unit each - sequentially impacted via electronically controlled series resistances in the form of transistors in such a way with specific operating curve shapes that in some of the cycles, the potential application of the target object will result in the latter's atomization and, in the intermediate sections, the charge coating will be reduced by the mentioned target object due to the field buildup along the auxiliary segment. /4

The last-mentioned United States patent conducts the surface charge coating via a special "suction" circuit; on the other hand, DE-PS 31 42 900 shows the route of subordinating sequential neutralization phases to the ionization phases during which the built-up charge coatings are neutralized.

According to DE-PS 31 42 900, looking at an ion-plating process, a low-voltage glow discharge section is provided between a glow cathode and an anode. The glow discharge is ignited during the ionization phases, the essentially neutral

material that is evaporated by an evaporation crucible is ionized and is accelerated upon the workpiece that was connected to a negative potential. Plasma and thus ion generation are stopped during the neutralization phases, and the electrons, emitted from the glow cathode, are used for neutralization of the ion surface coating on the workpiece surfaces. The glow discharge segment is operated by means of a flip-flop circuit with corresponding circuitry.

EP-A-0 101 774, in turn, proposes a technique in case of a glow discharge that is operated in the "abnormal" mode to prevent it from tipping over into the arc discharge mode. Regarding the definition of this mode, reference is made, for instance, to US-PS 3 625 848, Fig. 1. For this purpose, a current measurement is performed on the glow discharge segment and resistance is connected in to limit the current as a plasma arc is generated. In that way, one can counteract an already generated arc discharge between the glow discharge electrodes.

EP-A-0 062 550 proposes operating the glow discharge by pulses in case of a reactive treatment process. In order to be able to adjust the workpiece temperature with the temperature of a treatment furnace independently of the plasma discharge, "cold" plasma is generated in that between the pulses, the supplied electric energy is lowered so that the plasma discharge will not just be extinguished.

DE-PS-33 22 341 furthermore reveals the idea of using the following method to solve problems where, in case of a glow discharge operated with the highest possible voltage, there is the danger that the glow discharge might tip over into an arc discharge (see, for example, EP-A-0 101 774), and that, in case of a discharge operated with direct current, there is an additional disadvantage by virtue of the fact that the pressure and the temperature are coupled together - the solution being that the glow discharge intermittently is operated in each case with a pulse peak for ignition and then a signal range for the purpose of maintaining suitable levels for the glow discharge. This touches on processes with otherwise known direct-current-operated glow discharge.

US-PS-3 437 784 also has the objective of - in case of a glow discharge - preventing the transition into the arc discharge mode with a local arc between the electrodes. This is achieved in the following manner: A two-way-rectified, network-frequency signal is supplied to the glow discharge segment where the amplitude of the half-waves is so chosen that the glow discharge is ignited in some half-wave segments [and] is extinguished in the adjoining ones so that ions in an arc discharge path in the process of formation can be recombined. If the recombination time spans made available by the half-waves are not sufficient in accordance with the half-wave phases below

an ignition voltage level, then by means of a mechanically activated synchronous rectifier in the form of a series switch, a power supply separation is made between mutually following ignition phases.

US-PS-4 863 549 describes a high-frequency etching process where the glow discharge is high-frequency operated and where the atomization ion flow is steered upon the workpiece by means of a mid-frequency signal (90-450 kHz) and in the process - in order not to have to alter the amplitude of the last-mentioned signal - by means of pulse pack width modulation.

EP-A-0 432 090 discloses a reactive ion-plating process where a glow discharge segment is maintained between the glow cathode and a furnace with material to be vaporized and where the vaporized material is ionized.

A workpiece carrier is operated with a pulsating direct voltage relating to a reference potential, be this an anode potential or a cathode potential of the glow discharge. Using the pulsating operation of the workpiece carrier section, one can deposit especially good ceramic layers upon the workpieces.

The pulsating direct voltage is generated as a modulable rectangular pulse group by means of a specially provided pulse generator.

DE-PS-37 00 633 finally discloses the idea of maintaining a glow discharge or an arc discharge by means of direct-current

pulses - rectangular pulses - from a pulse voltage source. This is done in order to treat the workpieces in a thermally careful manner.

Getting back to the invention at hand: When one uses the invention-based process, especially due to the fact that charge coatings can now be mastered, one gets basically novel treatment methods. From its very first aspect on, the invention is not only confined to replacing previously known electrical power supply setups by simplified ones. This is true, although the existing systems with direct-current power supply without any further additional steps involving an additional module to be provided through the invention and without any major technical effort, can be converted for processes that in the past could be performed only in an extremely trouble-prone manner - start disorders due to oxide coatings of metal surfaces - or not at all with the help of direct-current generator power supply. /5

We now proceed according to the text of Claim 4; therefore, one gets an extremely simple type for altering the direct-current signal of the generator, and the repetition frequency and the pulse-width repetition rate can be adjusted in a simple and optimal fashion.

By selectively choosing repetition frequency and pulse-width repetition rate during the chopping phase, which preferably is designed according to the text in Claim 5, one can

optimize the efficiency in a simple manner by chopping up the direct-current signal power supply only during necessary time segments and only as often as necessary in order - by feeding in a signal with a broad frequency spectrum, such as it is generated during the chopping of the direct-current generator output signal during optimally short phases in which the supplied power output is reduced - to prevent the appearance of interference discharge phenomena. Proceeding according to Claim 5, one also gets an optimum combination of the invention from its two aspects, which are "direct-current signal generator power supply" and "segment discharge."

As part of the description of the invention at its end, the essential sets of features and feature combinations of the invention are combined for easier comprehension. Then using Roman numerals, reference is also made to these combinations.

It is furthermore proposed in a preferred embodiment variant to follow Characteristic Set VI, that is to say, to carry out the process on at least one workpiece that has a surface made up of nonconducting or poorly conducting material that is treated, for example, covered with a conducting or nonconducting or poorly conducting layer and/or whose surface, no matter what its type, whether conducting or nonconducting, is coated with a layer consisting of poorly conducting or nonconducting material. In this case, the workpiece is then

deposited on one of the conducting surfaces specified in Claims 1 to 3 (Sets I to III).

In particular, it becomes possible on a workpiece with a nonconducting or poorly conducting surface to deposit a layer consisting of conducting material as specified in Characteristic Set VII.

An extraordinarily important case as a part of the invention-based process according to the text of Claim 6 (Set VIII) is the process of ion plating by means of which on surfaces made up of conducting, nonconducting or poorly conducting material, layers of nonconducting or poorly conducting material are deposited or where a conducting layer is deposited on the surface made up of nonconducting or poorly conducting material.

As mentioned earlier, the invention-based process, looking at it from all of its aspects, is generally suitable for PVD treatment processes, including also reactive PVD processes, or for plasma supported CVD processes, especially because all of these processes share one feature in common: Charge carriers are present in the treatment atmosphere. Naturally, the invention-based procedure can also be employed in other processes, such as, for example, thermal CVD processes when charge carriers are present in the treatment atmosphere.

Following the text of Claim 7 (Set XI), the invention-based process, looking at it from both aspects, preferably comprises a method where a plasma is generated in the vacuum atmosphere, be it a glow discharge of the variously known types or also an arc discharge or, in the known manner, a plasma generated by magnetic field or microwave coupling.

If the plasma is generated by a discharge between electrodes, then preferably, according to the text of Claim 8 (Set XII), the plasma is supplied starting as of one of the mentioned surfaces.

For reasons of stability, it turned out advantageous, following the text of Set XIII, to apply one of the electrodes as of which the plasma is supplied upon the potential of one of the mentioned surfaces even when none of the mentioned plasma-generating electrodes is used as one of the invention-based operated surfaces.

Furthermore, following the text of Claim 9 (Set XIV), the discharge or transfer behavior is preferably measured in the discharge circuit.

To recognize the significance of such a measurement, we would at this point already - without claiming any physical exactitude - try to explain the mechanism which, in the invention-based discharging action according to the text of

Claim 2 (Set II), might take place on the section involved between two conducting surfaces.

A poorly conducting or nonconducting material phase, the insulation coating of one of the mentioned conducting surfaces whose surface is exposed to the vacuum atmosphere with the charge carriers, acts as a condenser. One cap is formed by the conducting surface, which also forms a condenser plate. The second "condenser plate" is formed by the "interface" to the atmosphere that is provided with charge carriers. The atmosphere segment between the insulating surface and the second conducting surface forms a conducting connection thanks to the existing charge carriers. A charge coating of the mentioned nonconducting or poorly conducting surfaces or corresponding surface areas or islands will correspond to the charging of the mentioned condenser. /6

Starting with this model, it is that condenser that, according to the invention, is specifically discharged or transferred via the discharge or transfer current branch. Instead of giving sufficient time for recombination to the ions forming the charge coating by means of corresponding signal shaping of a possibly connected electrical supply signal in accordance with the invention, the condenser, charged by the mentioned charge coating, is discharged - or possibly transferred - in a highly simplified manner and extremely

quickly by at least brief short-circuiting. As a result, the charge coating on the nonconducting or poorly conducting surface usually formed by positive ions is very quickly neutralized as part of the high mobility of the electrons in the vacuum atmosphere. On the mentioned surface, there is formed a generally electrically neutral double charge layer. The term "discharging" is to be construed rather as "neutralizing" on the basis of this mechanism.

The surfaces of the insulation coating, covered with the charges of the series-connected impedance of the atmosphere, behaves with respect to the other conducting surface in a first approximation like the series connection of discrete resistance as capacitance elements, something that is, of course, used for the sake of the invention; one can now readily see that the current flowing in the discharge or transfer time phases in the mentioned discharge circuit, such as it is measured in accordance with the text of Claim 9 (Set XIV), is significant for the charge coating as well as in the essentially constant substitute resistance of the mentioned segment with regard to the capacity value of the mentioned condenser and thus for the thickness of the insulation coating.

Neutralization, achieved according to the invention by the discharge short-circuit, is achieved in such short time intervals that, looking at the invention-based combination with

direct-current generator power supply, the discharge procedures now only minimally impair the efficiency of the actual direct-current signal supplied process and nevertheless facilitate this type of power supply.

Here is another essential fact: It is especially in processes where the ion coating, accompanied by material coating, is the process goal, as in ion plating, where, during the invention-based neutralization of the charge coating, there is essentially no further material evacuation away from the coated surface, but instead, the charge neutralization takes place by means of additionally deposited, opposite-pole charge carriers. The mentioned charge coating is neutralized electrically, something that is very important to process control and the result deriving from the process.

Following the text of Set XV using the measured discharge or transfer behavior, one can draw conclusions as to the thickness of a nonconducting or poorly conducting layer on one of the mentioned surfaces. From the time constants of the particular discharge behavior which, as is known and in the case at hand - close to ion conduction - does not depend on the amount of charge coating on the particular prevailing capacitance value, one can thus at least draw conclusions as to the layer thickness that increases from discharge cycle to discharge cycle: with increasing layer thickness, the discharge

time constant decreases. In this case, one can thus draw conclusions as to layer growth from the observation of these time constants.

On the other hand, according to Set XVI, looking at the measured discharge or transfer behavior, one can also draw conclusions as to the coverage with charge carriers because the level of the discharge behavior (initial value) does, of course, depend on the resistance value of the atmosphere segment but not on the capacitance value of the condenser, but, above all, on the charge state of the mentioned condenser and thus on the charge coverage.

It is especially in methods where the process goal is once again to deposit charge carriers that are to be neutralized upon a workpiece surface that it may be extraordinarily advantageous according to the text of Set XVII to measure the buildup of the charge coating on the insulation coating. This is possible, for example, in the following way: The considered conducting surface is applied to a reference potential via a charge amplifier and the charge flowing in this measurement branch, a function of the charge coating being built up, is measured.

According to another embodiment variant following the text of Claim 10 (Set XVIII), the measured discharge or transfer behavior is compared as ACTUAL behavior with a REQUIRED behavior and, as a function of the result of the comparison, the charge

coating is so altered by external charge supply and/or change of the discharge or transfer cycle frequency and/or the change of the discharge or transfer cycle length that the resultant measured ACTUAL discharge or transfer behavior will at least be approaching the REQUIRED behavior.

Here is another approach: It involves the preferred procedure according to Claim 11 (Set XIX) above all for plasma atomization. Accordingly, one observes spontaneous discharge phenomena caused by charge coverage and, depending on the frequency of manifestation and/or the type of manifestation, the charge coating is so controlled or regulated by external charge supply and/or change of the charge or transfer cycle frequency and/or change of the charge or transfer cycle length that one achieves a desired form of behavior regarding the mentioned spontaneous discharges. /7

It is furthermore proposed in a preferred manner according to the text of Claim 12 (Set XX) when measuring the discharge or transfer procedure to check and see whether the latter achieves a predetermined state and then to break that procedure off. In that way, one can make sure that, practically adapting to the particular discharge behavior, the discharge cycle time spans will be kept optimally short, and this can be done with simple technical signal means.

It is furthermore proposed according to the text of Claim 13 (Set XXI) during phases between discharge or transfer cycles to steer a charge coating buildup by means of external supply of a charge upon the surfaces or the insulation-coated surface to be coated. In that way, it becomes possible in the case of methods where the object of the invention in the abovementioned sense is to bring about a coating, while this, due to the process itself, is accompanied only by a charge coating to make sure that the rate of coating buildup can be controlled or regulated, whereby the latter is neutralized only as a coating occurring in the form of a charge coating in an electrical manner during the subsequent discharge or transfer cycles and where it remains as neutralized coating or layer on the target surface, be it as a conducting or as an additional nonconducting or poorly conducting layer on an isolation coating or be it on one of the conducting surfaces in the form of a layer that once again acts as insulation coating.

According to the text of Claim 14 (Set XXII), in a preferred exemplary embodiment, the charge coating buildup is thus so controlled as layer buildup on at least one workpiece during ion plating.

When a plasma discharge is maintained between electrodes, then via these electrodes, one must supply the energy necessary for the maintenance of the discharge if additional energy, for

example, inductively, is not coupled into the discharge space. Between such electrodes, we thus find not only a potential difference but a considerable current also flows, in other words, the plasma discharge current.

This is not the case in segments where at least one of the electrodes is not directly involved in the maintenance of the plasma discharge, in other words, in sections by means of which, for example, a workpiece is kept on potential in the treatment space in terms of a bias operation, such as, for example, during the potential application of workpieces during ion plating in such a way that an acceleration field will work on the workpiece surfaces for the positive ions in the discharge space.

The supply of such segments is relatively poor in output. As mentioned earlier, the moved ions or complex ions involve relatively large particles with relatively low mobility.

This basic difference can be used specifically in connection with the last-mentioned methods. This is achieved according to the invention by means of a preferred invention-based process according to the text of Claim 15 (Set XXIII).

In series with the invention-based employed condenser - formed by the insulation coating, the nonconducting or poorly conducting workpiece surface itself that can be made already by means of coating or an insulation coating made during the process, that is to say, a deposited layer of nonconducting or

poorly conducting material - during plating phases, a discrete capacitance is connected, and this series circuit during the mentioned plating phase is so charged up by means of externally supplied charge that, first of all on the plasma discharge segment between the workpiece carrier electrode and the considered additional metallic surface, an electrical field is generated that is so directed that positive ions are accelerated toward the workpiece surface, as a result of which, on the latter finally due to the series circuitry, a rectified voltage is built up as on the discrete capacitance by dimensioning of the previously mentioned, externally supplied charge so that in the end, the rate of deposited layer-forming ions on the workpieces will be controlled.

Imparting a given charge with a given course upon the series circuit of two capacitive elements, the discrete capacity and the condenser used according to the invention is readily possible, as any expert knows, due to the differentiated behavior of a capacitance by applying a voltage with a predetermined time derivation.

If thereafter during the discharge phases capacitance and condenser are connected parallel, then by virtue of the discharge process of the discrete capacitance, the particular condenser used according to the invention formed by the insulation coating on the workpiece is supported. If, in

particular, the discretely series-connected capacity is chosen considerably larger than that of the coating condenser, then the latter is essentially transferred to the voltage on the discrete capacity. By measuring the capacitance ratio of the discrete capacitance and of the condenser used according to the invention, one can determine the discharge or transfer measure, in particular, on the last-mentioned condenser.

The charging, especially of the mentioned condenser, preferably takes place according to the text of Claim 16 (Set XXIV). This again is done in a preferred manner according to the text of Claim 17 (Set XXV) in that, as mentioned, a voltage with predetermined or predeterminable course of its change is connected in terms of time. /8

That can take place, for example, according to the text of Claim 18 (Set XXVI) by means of inductive voltage raising in the series circuit or preferably in the following manner: According to the text of Claim 19 (Set XXVII), the series circuit is charged up during the plating phases by means of a ramp voltage essentially with a constant current, and thus one can generate an essentially constant charge coating rate. Naturally, the particular ramp used here and the particular essentially constant current need not necessarily be a linear ramp or an absolutely constant current but rather, by designing the voltage curve shape depending on the time requirement, the time frame of

the current can be controlled, and that means that the coating rate per unit of time can also be controlled.

In another embodiment variant according to the text of Claim 20 (Set XXVIII), one provides two or more pairs of the mentioned surfaces and two such pairs each or two such groups of pairs each are operated with a direct current generator and/or with a discharge or transfer current circuit, and this is done in a time-phase manner. If several of the mentioned pairs were to be operated synchronously in terms of time according to the invention at hand, that is to say, either synchronized in terms of time if additional signals were applied on the output signals of the direct current generators and/or if too many of the mentioned pairs were to be discharged or transferred in terms of time synchronization, then under certain circumstances, there would be an impermissible impairment of the treatment conditions in the vacuum chamber.

One can thus readily see that, for example, by means of the discharge or transfer processes, electric energy is taken out of the treatment space. If that would turn out to be too high, considering the many simultaneous discharge procedures, then instabilities might develop, for example, on a plasma discharge.

It is therefore proposed in these cases to proceed according to the invention in a time-phase manner. In

particular, according to the text of Claim 21 (Set XXIX), one proceeds in this fashion during ion plating.

By means of the time-phase discharging of the invention-based operated two pairs or groups of described surfaces, energy is not at the same time taken out of the plasma discharge process.

According to the text of Set XXX, it is furthermore proposed, specifically during ion plating, to measure the discharge procedure, to compare it to a REQUIRED procedure and, by varying the charge of the series circuit during the plating phases as a function of the comparison result, at least to adapt the charge coating by ions on the workpiece and thus possibly considering changes in the condenser determined during the discharge procedure from the time constant changes to the REQUIRED procedure [by means of the] measured discharge procedure [sic].

Especially with relation to the invention-based use of an ion-plating method, it is proposed, following the text of Set XXXI, to perform the discharge procedure with a repetition frequency of 50 kHz to 500 kHz, preferably at least 90 kHz, and particularly preferably with at least 100 kHz.

Preferably, in an invention-based process, which comprises ion plating according to the text of Characteristics Set XXXII, at least one corrosion-resistant and/or at least one wear-and-

tear-proof layer is generated, for example, a nonconducting or poorly conducting first layer as corrosion-protection layer, and a second conducting layer as wear-and-tear protection layer, or other combinations of layers also as a layer system with two or more layers to be to be deposited on at least one workpiece.

Another preferred invention-based process, along with those involved in the use of ion plating according to the text of Claim 22 (Set XXXIII), is distinguished by the following: In the mentioned vacuum atmosphere, a conducting material is atomized by means of a plasma discharge, be it an arc discharge or a glow discharge. The plasma discharge is maintained between the material to be atomized and a counterelectrode, and the atomized material enters into a nonconducting or poorly conducting material combination with reactive gas that is piped into the vacuum atmosphere.

The control discharge circuit is provided over the plasma discharge segment and, series-connected on top of that, the direct current signal generator and an interruption switching segment, whereby the latter and the connection of the discharge current circuit are energized intermittently [sic].

In that way, there can be no problems of an insulation coating that would set in independently of the process prior to the coating of the conducting material that is to be atomized as well again during the process itself with the connection formed

by the reactive atomization process in terms of the mentioned stochastic or spontaneous discharge phenomena, which means that as of the start of the procedure, the process can be conducted in a stable fashion in spite of the use of a direct-current signal generator as the main energy source.

According to the text of Characteristics Set XXXIV, especially when the direct-current signal generator has current source characteristics, one can bridge the interruption circuit segment by means of a network, preferably a passive [network] and preferably a resistance network. In that way, one can make sure that during interruption phases between generator output and plasma discharge segment during which at least the discharge current is connected for a short time, only a limited voltage is applied via the interruption circuit segment, which must thus be connected [sic]. /9

According to the text of Characteristics Set XXXV, the invention-based reactive cathode atomization process is operated in the oxidic or in the transition mode. In a preferred embodiment variant, silicon is cathode atomized and is made to react with oxygen to form a silicon oxide Si_xO_y, in particular, SiO_2.

Generally, according to the text of Characteristics Set XXXVII using the invention-based reactive cathode atomization

process, one can generate dielectric or poorly or semiconducting layers on a metal base.

According to the text of Characteristics Set XXXVIII, looking at the invention-based procedure, in particular, during the mentioned cathode atomization process, certain sub-processes are formed, the additional signal is applied with a frequency corresponding to 50 Hz to 1 MHz, preferably corresponding to 5 kHz to 100 kHz, particularly preferably 10 kHz to 20 kHz.

According to the text of Characteristics Set XXXIX, in a preferred manner, furthermore, the additional signal is in each case applied with lengths of 50 nsec to 10 μsec, preferably from 0.5 μsec to 2 μsec or from 2μsec to 10 μsec. This is naturally done in coordination with the particularly preferred employed repetition frequencies.

The invention at hand, looking at the third aspect, also relates to a process for controlling the charge coating on a surface of one part, which surface is formed by a nonconducting or poorly conducting portion of the part or a nonconducting or poorly conducting coating of the part, whereby the part is connected with one of the conducting surfaces and where the surface lies in a vacuum treatment atmosphere with charge carriers. Here a charge is made in a controlled manner via the surface, the part with the area, a segment of the vacuum atmosphere and an additional conducting surface that is an

effective contact with the vacuum surface, this being done especially during a plasma treatment procedure according to the text of Characteristics Set XL.

The following is thus basically facilitated: using the abovementioned analogy of insulation coatings and condenser, on those surfaces during any vacuum treatment processes where charge carriers are present in the vacuum atmosphere to control a desired charge coating of the mentioned surfaces.

Problems underlying the invention at hand, looking at its first and second aspects, are solved by vacuum treatment systems according to the text of Claim 23 (Set XXXXI) or 24 (Set XXXXII) in a preferred combination according to text of Claim 25 (Set XXXXIII).

Additional preferred embodiment variants of the invention-based systems with the advantages explained on conjunction with the preferred embodiment variants of the processes involved are specified in Claims 26 to 46 and in Characteristics Sets XXXXIV to LXXI with preferred practical uses in Characteristics Sets LXXII and LXXIII to LXXIV and LXXV.

The invention will now be explained by way of examples with reference to the figures.

Fig. 1a and 1b:	schematically, on the basis of a functional block diagram for each known procedure during the electrical power supply of insulation-coated, electrically conducting areas in vacuum treatment chambers;

Fig. 2 on the basis of a functional block diagram, the basic invention-based procedure in connection with the mentioned electrical power supply, looking at the first aspect of the invention at hand;

Fig. 3 the invention at hand, looking at its second aspect, in an illustration resembling the one in Fig. 2;

Fig. 4 showing the procedure according to the invention at hand in an illustration similar to Figs. 1 to 3 with a preferred combination of its aspects, as illustrated individually and basically in Figs. 2 or 3;

Figs. 5a to 5c schematically and without any claim as to any scientific exactitude, the illustration of a segment in a vacuum treatment chamber with nonconducting or poorly conducting material coating, an insulation coating, in order to exchange the charge coating phenomena, and their invention-based neutralization as well as the valid substitute picture in a first approximation;

Fig. 6 on the basis of a functional block diagram, the invention-based procedure or basically an invention-based treatment system from both of its aspects in a preferred basic form of implementation, whereby, looking at I and II, one can see preferably combined inventive aspects in this system; /10

Figs. 7a to 7c schematically, three exemplary embodiments to influence the discharge behavior or transfer behavior used according to the invention by means of external charge supply, illustrated with the help of electrical substitute images;

Fig. 8	a functional block/signal flow chart of a preferred embodiment variant of the invention-based procedure where the discharge behavior is measured and the discharge cycle time span is optimized;
Fig. 9	schematically, the effects on the discharge time constant of the thickness growth of a nonconducting or poorly conducting layer on a conducting area used according to the invention - the insulation-coated area;
Fig. 10	another embodiment variant of the invention where the discharge behavior is measured, where it is compared to a REQUIRED behavior and where in terms of regulation one interferes with the discharge cycle sequence or the length of the latter and/or where a charge is additionally coupled into the discharge circuit;
Fig. 11	on the basis of a functional block/signal flow diagram, the invention-based procedure basically for controlling a charge coating on an insulation coating, which lies on conducting areas connected into a discharge circuit in an invention-based manner;
Figs. 12a to 12c	a preferred embodiment variant of an invention-based process for reactive ion plating with (Figs. 12b and 12c) that substitute images that are at least close to the arrangement according to Fig. 12a depending on the operating phase;
Fig. 13	a first preferred embodiment variant of the procedure or the system according to Fig. 12a;
Fig. 14	schematically, on the basis of a functional block/signal flow chart, an additional preferred embodiment variant of the procedure or the system according to Fig. 12a or 13 where, the mentioned charge coating is controlled in the plating phases;

Fig. 15 on the basis of a schematic system configuration according to the invention at hand, a preferred potential application of a plasma discharge segment electrode and a conducting area operated in accordance with the invention;

Fig. 16 an additional preferred embodiment variant of the invention at hand for reactive atomization with the invention-based use of a direct-current signal generator;

Fig. 17 schematically, on the basis of a functional block/signal flow diagram, an additional preferred embodiment variant of the invention-based procedure or an invention-based treatment system, where the frequency or the type of occurring spontaneous discharge phenomena is acquired and where, as a function thereof, the invention-based discharging and/or possibly the invention-based triggering of the applied charge coating is adjusted in regulating terms;

Fig. 18 on the basis of a schematic functional block/signal flow chart, the invention-based procedure or an invention-based system, whereupon several segments of electrically conducting area pairs are operated in accordance with the invention but in a time-phased manner;

Figs, 19, 19a-19h schematically, some exemplary embodiments of the invention-based method or invention-based constructed treatment system in various configurations.

Figures 1a and 1b represent procedures or system configurations according to the state of the art.

In a vacuum receptacle 3 in whose vacuum atmosphere charge carriers q are present, conducting areas 2a and 2b, or the

vacuum atmosphere segment located between them, are to be operated electrically in such a manner that an electrical field will take effect between the areas. Here, at least one of the areas 2a and/or 2b is provided at least partly with a coating of poorly or nonconducting material, hereinafter called "insulation coating." The insulation coating here can be an interference layer that is independent of the treatment process, such as an oxidation layer on a metal area, or it can be a layer previously applied on a conducting surface consisting of nonconducting or poorly conducting material or a layer applied during the considered treatment procedure consisting of the mentioned nonconducting or poorly conducting material, be that a layer that is the objective of the treatment process or be it an interference layer during the treatment process. /11

Insulation coating is shown schematically at 4. Except in the case where we are dealing in case of insulation coating 4 with a dirt contamination layer, such as an oxidation layer of a metal surface which, for example, was generated in a normal atmosphere, such a segment is operated between areas 2a and 2b in a first variant usually with an alternating current generator 6, a generator that essentially produces sinusoidal output signals or, as illustrated schematically, a pulse group, possibly with different pulse-width repetition rates (duty cycle).

Under the mentioned conditions, Fig. 1b shows another known procedure according to which one superposes on the output signal of a direct-current generator 6a the output signal of an alternating current generator 6b, as illustrated in technical signal terms at 7. This procedure is chosen because, upon application of a monopolar electrical field between conducting areas 2a and 2b, a charge coating is built up on the insulation coating, for example, in case of a negatively polarized area 2b, of positive charge carriers, ions and, accordingly, as will be described later, a voltage is built up via the insulation coating 4. When the corresponding voltage values are attained, then there will be spontaneous discharge phenomena - corresponding to local conditions - be it through the insulation coating, superficially along the insulation coating, upon the area 2b and/or toward other neighboring, correspondingly polarized system parts.

Fig. 2 illustrates the invention-based procedure or, schematically, it shows a corresponding invention-based system. Areas 2a and 2b are supplied according to the invention by a direct-current signal generator 8. An additional signal is connected to the output signal of the direct-current signal generator 8 with predetermined frequency or predeterminable frequency, and throughout the predetermined time phases or predeterminable time phases controlled by a clock generator 10

and as illustrated schematically by switch S, which additional signal, as shown schematically, is brought about by a signal generation unit 12, it is shaped in whatever way it may be so that a signal, deviating from the output signal of generator 8, is connected to the segment between areas 2a and 2b at the predetermined or predeterminable times and during the predetermined or predeterminable time phases.

Looking at unit 12, this can be a specially provided signal generator which, however, needs to be designed in such a way that in keeping with its connection frequency and in accordance with the connection time spans, it can supply the required output to the section between areas 2a and 2b. As will be shown later, this, however, preferably in the case of unit 12, involves a unit by means of which, essentially in a passive manner, the output signal of the direct-current signal generator 8, as indicated and controlled in terms of time, will be changed.

Fig. 2 shows the basic invention-based setup, looking at it from its first aspect, that is to say, the aspect where the section between the mentioned surfaces 2a and 2b must be supplied electrically, this being done in accordance with their use in the context of the intended treatment process.

In a similar manner, Fig. 3 illustrates the invention-based procedure for a corresponding system, looking at the second

invention-based aspect, that is to say, the aspect where the two areas 2a and 2b need not be supplied electrically, such as, for example, when one of the areas is operated in a potential-floating manner in the course of a plasma discharge process. According to the invention, the two areas 2a and 2b upon at least one of which lies the insulation coating 4 are connected via a controlled discharge circuit, as illustrated in Fig. 3 with discharge switching unit 14, which is triggered by a clock unit 16. Thus, the frequency is predetermined or predeterminable, that is to say, the occurrence with which the section between areas 2a and 2b is short-circuited at least for a short time. By the same token, the length of the time phases during which the discharge circuit current is connected through by unit 14 is predetermined on unit 16 or can be predetermined thereupon.

Neither the frequency nor the time phases here need to be time-constant during a considered treatment process in the vacuum atmosphere with the charge carriers q; instead, both magnitudes can, depending on the development of the process and the type of the process, be managed in a manner to be described later on.

Fig. 4 shows a preferred embodiment variant of the invention-based process or a corresponding system where the procedures or the system configurations are combined in

accordance with Figs. 2 and 3. For this purpose again, the through-switching unit 14 is triggered via the segment formed by areas 2a and 2b by means of time control unit 16 and the direct-current signal generator 8 is connected via the through-switching unit 14 [sic].

As one can see now, the through-switching unit 14 is in a highly advantageous manner used both in terms of a discharge current circuit through-switching unit and as switching unit S in accordance with Fig. 2 by means of which the output signal of the direct-current signal generator 8 is altered with predetermined or predeterminable frequency and during predetermined or predeterminable time phases. Accordingly, clock unit 16 at the same time works as clock unit 10 according to Fig. 2, and the through-switching unit 14 itself works as switching unit S and as unit 12 in accordance with Fig. 2 to generate the signal deviating from the output signal of generator 8. /12

In this combined function, furthermore, through-switching unit 14 is labeled with reference symbol 14_s and clock unit 16 is labeled with reference symbol 160.

The basic principle that is considered here by the invention at hand, looking at it from its two aspects but especially from the second aspect, will not be explained without

any claim as to physical exactitude with reference to Figs. 5a to 5c.

Fig. 5a is a diagram illustrating the vacuum receptacle 3, specifically in the vacuum atmosphere, the charge carrier q, for example, and especially generated by a plasma discharge PL [sic]. Once again, the two invention-based-operated conducting areas 2a and 2b are shown here along with an insulation coating 4. Now let us charge-coat surface O of insulation coating 4, especially with the schematically illustrated positive ions.

Formed on the surface of insulation coating 4 facing toward electrode 2b, there is a charge coating that is diametrically opposed to the outer charge coating, as illustrated in the diagram. Insulation coating 4 forms the dielectric of a condenser, shown in the substitute illustration according to Fig. 5b with the symbol C_1, one of whose plates is formed by area 2b, whereas the other one is formed by surface O adjoining the segment of the vacuum atmosphere that is conducting due to charge carrier q.

This vacuum segment can basically be illustrated with the impedance Z_P, whereby at least in a first approximation, this impedance can be considered as being ohmic. This can be done because the mobile electrons in the vacuum atmosphere in a first approximation guarantee proportionality between the field intensity and the charge shift.

According to the invention, that is to say, according to the invention-based second aspect looking at Fig. 3, the vacuum atmosphere segment between areas 2a and 2b is short-circuited intermittently. When a charge coating has taken place as in Fig. 5a, then via condenser C_1, there is a voltage according to U_{C1} as shown in Fig. 5b. If the switching segment S_1 is closed in accordance with the through-switching unit 14 shown in Fig. 3, then, furthermore, the sum of all voltages in the discharge current circuit must disappear. As shown in a simplified manner in Fig. 5c, the following situation quickly develops: Upon closing switching segment S_1, there is first of all built up via impedance the voltage, shown in broken lines in Fig. 5b, which is also entered in Fig. 5c and, as a result of which, quickly movable electrons are driven against surface O. That forms an electrical double layer adjoining that surface without any essential change in the ion charge coating, which double layer is charge-neutral as a whole.

Thus, by closing switching segment S_1, the charge coating is neutralized without, however, the ion coating being essentially disturbed in the process. This problem, however, is caused by the electrical charge coating according to Fig. 5a which, when the corresponding voltage attains glow or spark values, leads to the described spontaneous discharge phenomena.

It might be mentioned at this point that in the described procedure, apart from the solution of the mentioned problems resulting from spontaneous discharges, one can make it possible to begin with to apply on nonconducting or poorly conducting layers - or on surfaces in general - in terms of the mentioned insulation coating certain layers by means of ion plating, or one can apply on conducting surfaces nonconducting or poorly conducting layers in terms of the mentioned insulation coating generated during the process.

The time constant of the "discharge procedure" or "transfer procedure" occurring upon closing the switching segment S_1 due to the heuristically explained mechanism given essentially by the capacitance value of condenser C_1 and the "resistance value" essentially given by the electron mobility of the vacuum atmosphere provided with charge carriers in accordance with an impedance Z_P. This time constant, of course, can be influenced by external connection of the discharge current circuit, be it by providing likewise variable resistance elements, but if necessary, the discharge current circuit can beforehand, in an approximately first-order manner, be expanded into a system of the second order by connecting additional impedance elements such as inductivities.

As part of the invention at hand, it is, however, first of all important to make sure that the charge coating remaining

after a discharge procedure on condenser C_1 can be influenced by connecting charge-driving sources into the discharge circuit and, furthermore, particularly with a view to the mentioned ion plating, that during phases in which the switching segment S_1 is opened, the charge coating buildup can be controlled or adjusted by external charge feeding into the segment between areas 2a and 2b, as will be explained later on.

Before we touch on additional preferred embodiment variants, we might, looking at Fig. 6 with a view to Figs. 2 to 4, once again explain the concept behind the invention at hand, looking at it from its various aspects.

Fig. 6 schematically illustrates the invention-based processes or invention-based systems from their two aspects and in preferred practical implementation forms. Vacuum receptacle 3, where preferably a plasma discharge PL is maintained, is possibly provided with an inlet 18 for a reactive gas or a reactive gas mixture. Between conducting areas 2a and 2b or over the segment formed between them in vacuum receptacle 3 as part of a preferred embodiment variant of the procedure or the system according to Fig. 4, there is connected a unit 14_s that works as a chopper unit and, furthermore, via the chopper unit 14_s of the equivalent [sic] via the chopper unit 14_s, there is connected the direct-current signal generator 8. Chopper unit 14_s is energized by the preferably controlled clock generator

160. Chopper unit 14_s, preferably formed with electronic circuit elements, such as switching transistors, MOSFETS, thyratrons, thyristors, spark gaps, saturated chokes, etc., as mentioned, is positioned parallel over the conducting surface areas 2a and 2b and the segment located between them and forms the discharge current circuit via the mentioned segment. /13

As the expert knows, steps are taken - possibly and as will be described specifically later on - in order as switching segment S_1 is switched through not simply to short-circuit the direct-current signal generator 8 on chopper unit 14_s.

Looking at the first aspect (I), shown with the broken line in Fig. 6 and encircled under I, the invention thus comprises the simple combination of a direct-current signal generator 8 and a short-circuit chopper unit 14_s via which the stretch between areas 2a and 2b on the vacuum treatment system is operated electrically. In that case, an existing system, driven by a direct-current generator, can, by providing chopper unit 14_s, be further developed in a simple manner to perform treatment methods with direct-current supply that otherwise cannot be performed or that otherwise can only be poorly performed.

Looking at the second aspect (II), the invention, as mentioned earlier, also exclusively encompasses providing chopper unit 14_s, which possibly can also be provided between electrodes that are not supplied electrically, but rather one of

which, for example, is applied to reference potential, such as ground potential, and the second of which is normally operated in a potential-floating manner where its potential is adjusted in accordance with the potential distribution in the vacuum atmosphere. In these types of segments between conducting areas 2a and 2b, it may also be entirely desirable to reduce the charge coatings which influence the floating potential of one of the conducting surfaces or electrodes so that the invention-based discharging with chopper unit 14_s is considered as an inventive part of the invention at hand. This part of the invention at hand is edged with a dot-dash line in Fig. 6 and is labeled II.

Fig. 7a describes the provision of a charge source in the discharge circuit that is provided according to the invention and that is described in Fig. 5, which charge source during the discharge phases, for example, when switching segment S_1 is connected through, is connected to the segment between areas 2a and 2b. For this purpose, a charge source 20, for example, in the form of a current pulse source, is connected, triggered, or steered in the mentioned discharge current circuit, as shown schematically, essentially synchronously with the closing of switching segment S_1 by clock generator 16 or 160, depending on whether one uses the configuration illustrated in Fig. 7a, as

shown in Fig. 3, or in the combination configuration, as basically shown in Fig. 4 or 6.

In that way, when closing switching segment S_1, charge is applied with predetermined polarity upon condenser C_1 and the charge coating at the start of a discharge cycle is raised or lowered as desired. In particular, in that way, one can shorten the discharge cycle in that in the extreme case, the entire charge coating on condenser C_1 can be neutralized by the externally applied charge.

Here it must, however, be kept in mind that when an independent discharge procedure is furthermore intended in the mentioned discharge current circuit, the impedance in the discharge circuit may not be impermissibly increased in the discharge circuit by introducing the charge source 20 in order not to increase the discharge time constant above the desired measure.

Fig. 7b shows a first embodiment variant designed for accomplishing the external charge influencing of the condenser C_1. With switching segment S_1 open, a discrete capacitance C_D is charged by a current source 22 with desired polarity, such as, for example, as entered.

If switching segment S_1 is connected through, we now witness the discharge or transfer behavior of the entire circuit on the basis of the relationship of the capacitance values of C_1 and C_D

as well as the particular charge ratios as initial conditions, which the expert, of course, is entirely familiar with.

If during phases when S_1 is opened the charge that is built up on C_1 is acquired, then this charge can be neutralized with the charge source described here.

Possibly, the switching segment S_1 can then be eliminated; in one group of phases, the charge coating is acquired, and in the others, it is neutralized.

Looking at the preferred embodiment variant shown in Fig. 7c, a voltage source U_E is switched into the discharge current circuit in such a way that the discharge behavior will result on the basis of the difference between the charge voltage at C_1 and U_E. In that way, by virtue of the amount and polarity of the voltage U_E, one can influence the discharge or transfer behavior of condenser C_1. Preferably, the discharge behavior is thus accelerated in certain cases in the sense that a predetermined, fading [paling] discharge voltage is achieved faster on C_1 than when the considered segment is only directly short-circuited.

An essential advantage of the discharge process, used according to the invention, consists in the following: A discharge or transfer procedure can be tracked by measurement technology. This can be done preferably by means of current or charge measurement in the discharge current circuit. /14

This will now be explained by way of example, referring to Fig. 8. Accordingly, conducting surface 2b of the considered segment is applied to a reference potential Φ_0 and the section is extended via switching segment S_1 to the inverting input of a current amplifier or, as illustrated, a charge amplifier of the known design, as illustrated at 24. As will be shown later on by way of example, the differential amplifier to be used for this purpose is applied with its positive input upon the reference potential Φ_0. As switching segment S_1 is switched through, there will appear in the illustrated configuration on the output side of the measurement amplifier 24 the integral of the discharge current surge as is illustrated schematically via time axis t. As shown at A, the discharge or transfer behavior measurement can be used for various purposes that are yet to be discussed.

According to Fig. 8, it is preferably compared to a comparator unit 26 for which is predetermined the threshold value W from a reference signal source 44. If the output signal of amplifier 24 attains the adjusted threshold value W, as a result of which accordingly the discharge procedure has faded to a corresponding predetermined value, then, for example, a bistable element 30 is reset and the switching segment S_1 is opened. The bistable element here can be set by the rising

switching flank of clock generator 16 or 160 and switching segment S_1 can thus be switched through.

In that way, one can make sure that the discharge cycle will last only so long as this is necessary to attain a predetermined discharge state. In that way, only the smallest possible time spans are blocked for this discharge procedure and the rest of the time is available, especially when one uses the arrangement according to Fig. 8 in the configuration according to Fig. 4, for the energy supply starting as of the direct-current signal generator 8.

As one can readily see, the time constant τ of the discharge procedure depends critically on the capacitance value of condenser C_1. When the invention-based predetermination is used on the segment between conducting areas 2a and 2b within which a workpiece is arranged with a nonconducting or poorly conducting surface in terms of an insulation coating, such as, for example, a workpiece that is coated by a reactive coating procedure with an "insulation coating" as a desired layer, then with increasing layer thickness, the capacitance value of C_1 will decline with the known interval relation of the capacity value.

Thus, as shown schematically in Fig. 9, by analyzing signal A in Fig. 8, one can determine the discharge time constant τ that decreases as the layer thickness changes and, from that, one can draw conclusions as to layer growth.

Fig. 10 shows another embodiment variant according to which, by determining the ACTUAL discharge condition subsequent to comparison with a REQUIRED behavior in accordance with the comparison result, one can so interfere in a regulating fashion in the operating of switching segment S_1 that the discharge behavior at least in an approximate fashion will level out as REQUIRED behavior. For this purpose, as shown schematically, the discharge current I_E is tapped, as shown at 32, and a corresponding voltage signal, for example, is digitalized by means of an analog/digital converter 34. The digitalized measurement signal is stored in an ACTUAL value memory unit 36. The content of the ACTUAL value memory unit 36 is, in a comparison unit 38, compared with a REQUIRED discharge course that is stored in a REQUIRED value memory unit 40.

Using an analysis unit 42, the differences Δ between the REQUIRED curve and the ACTUAL curve is analyzed and is illustrated with the analysis result on the output side of analysis unit 42 as shown schematically with changeover switch N either to a controlled charge source 44 whose polarity can be reversed in order to influence the particular charge state of condenser C_1, while switching segment S_1 is opened so that its charge coating or, with the output of analysis unit 42, on clock generator unit 16 or 160, the follow-up sequence f of following discharge cycles is enlarged or reduced or, in case of constant

repetition frequency f, the pulse-width repetition rate (duty cycle) of the pulse group that on the output side of the clock generator 16 or 160 triggers the switching segment S_1 [sic]. If by energizing charge source 44 the discharge behavior is made to disappear, then this means that the charge coating is neutralized electrically by the effect of source 44. This again can be achieved by the illustrated control circuit.

One can, for example, then proceed cyclically in the following manner:

a) Open switch S_1; source 44 drives charge upon C_1, which corresponds to the buildup of a charge coating.

b) Switch S_1 continues to be open: source 44 is operated in an inverted manner for a short time and the resultant charge coating is neutralized in an electrically controlled manner.

c) Switch S_1 is closed, the discharge current is measured; depending on its remaining magnitude and polarity, the neutralization charge is set in a regulated manner in step b) and/or the charge coating control charge [is set] in step a) [sic]. /15

In the course of the description at hand, we will further touch on the previously mentioned external connection of a charge source, such as, for example, source 44 during phases in which the switching segment S_1 is opened. This will be done

especially in conjunction with ion plating as a part of the invention-based procedure.

By acting on the charge state of the condenser and/or the discharge frequency or the length of the discharge cycles, one can thus act on the charge coverage of condenser C_1 in a regulating fashion so that with a time-constant capacitance value of C_1, the discharge behavior and thus the charge coating will follow a REQUIRED value. This is also true when the discharge time constant varies with varying capacitance value of C_1 in that, from the discharge time constant τ, one can then draw conclusions as to the momentary value of the mentioned condenser, and from that and from the initial value of the discharge procedure, one can draw conclusions as to the charge coating on C_1.

Starting with the illustration according to Fig. 3 or in the combined configuration according to Fig. 4, Fig. 11 now shows how, basically according to one aspect of the invention at hand during time intervals between discharge cycles, the charge coating of insulation coating 4 can be influenced in a controlling, possibly regulating manner.

For the moment, we first of all want to look at Fig. 5 once again. When a charge is imposed in Fig. 5 outside the segment between areas 2a and 2b, then condenser C_1 is charged. If following customary current direction convention in the entered

direction a current i is imposed in accordance with a charge per unit of time, then this results in an increase in the charge coverage with positive ions on the insulation coating 4 and, accordingly, there will be a removal of this coating on insulation coating 4, that is to say, there will be an emigration of positive ions or an immigration of electrons in case of current reversal. It must be pointed out that current direction i is usually entered against the electron flow.

In that way, by externally applying a current or a charge, one can also control the charge coverage on the insulation coating. This is extraordinarily important, especially in all those treatment methods where a layer is to be applied with a charge application and thus material coating as happens especially in the case of ion plating. There, ions are deposited in a specifically targeted manner from the vacuum atmosphere upon a workpiece by means of electrostatic forces.

According to Fig. 11, for this purpose with switching segment S_1 opened, a charge flow is driven through the segment with the conducting areas 2a and 2b on unit 14 or 14_s in accordance with Figs. 3 or 4 with clock generator 16 or 160, as is illustrated schematically in Fig. 11 with charge source 46, which is operated synchronously with the through-switching of switching segment S_1.

Using the mentioned methods, such as they are used especially also for ion plating, the buildup of a layer on the nonconducting or poorly conducting surface of a workpiece or a layer consisting of nonconducting or poorly conducting material can be specifically influenced or controlled or regulated upon the conducting surface of a workpiece.

Figs. 12a to 12c schematically illustrated a preferred embodiment variant of the invention-based process or a correspondingly structured system. Material is evaporated in the known manner in a vacuum receptacle 1 from a crucible 52, for example, with a plasma discharge. This can be done by means of arc discharge or spark discharge upon furnace 52 or by electron ray evaporation of the material in furnace 52 or, as illustrated, by means of a low-voltage glow discharge between a glow emission cathode 50 and the furnace 52. Naturally, the material can also be evaporated or also atomized by means of furnace heating. The only essentially factor here is its ionization regardless of what kind the actual material source happens to be and regardless of whether the process, which forms the layer material, is or is not reactive.

By piping in gas 18, looking at the examples shown, a working gas is piped into the vacuum receptacle 1 with reactive gas parts, which, in the glow discharge, react with the material that is being evaporated out of furnace 52. Now ions are

formed. As reaction product, poorly conducting or nonconducting material in the form of positive ions is first of all deposited as charge coating on one or several workpieces 1 on the conducting surface 2a, which is made as workpiece carrier electrode. Workpieces 1 here either have a conducting surface and are coated by the plating method with a layer of nonconducting or poorly conducting material or they already have a surface consisting of nonconducting or poorly conducting material and are then covered with a layer of also nonconducting or poorly conducting material or with a layer of conducting material.

The process, on the one hand, permits ion plating with nonconducting or poorly conducting layers upon any conducting or nonconducting surfaces or ion plating with conducting layers upon nonconducting or poorly conducting layers on the workpiece or on nonconducting or poorly conducting workpieces. Such layer/workpiece systems in the past could be produced with ion plating only in a highly restricted fashion because the necessary monopolar plating currents could not be built up in the first place.

Next, as one can readily see, workpieces 1 will be impacted in this system configuration, which is to be described further, with multilayer systems, in particular, one can provide workpieces made of any conductible material with a nonconducting

or poorly conducting first layer, in particular, as corrosion protection layer, with a conducting second layer, in particular, as wear-and-tear protection layer, or with combinations of such layers, whereby more than only two layers can be built up. /16

The essential aspect for ion plating is represented by the fact that the layer materials to be deposited, as mentioned, are ionized in the vacuum chamber. This can be done in the most varied way, for example, with electron ray evaporation by dividing a plasma discharge such as an arc discharge upon the furnace. Ionization takes place during arc lamp evaporation or glow discharge evaporation through plasma discharge itself or the necessary ionization can be brought about by coupling in additional electrons or ions into the vacuum receptacle. Furthermore, one need not absolutely provide a reactive process when, for example, the evaporated material as such is to be deposited after ionization.

Furthermore, instead of evaporation, one can sputter the material. If a conducting material is sputtered, then the sputter source, such as a magnetron source, can be provided in place of furnace 52. If a nonconducting material is to be sputtered, then preferably, the sputter source is operated separately by means of a high-frequency discharge, and then, instead of furnace 52 for the further invention-based

connection, one can provide a conducting area independent of the discharge as reference area in the receptacle (see Fig. 19f).

At any rate, the conducting area 2a that acts as workpiece carrier electrode during ion plating must be so placed on potential that positive ions will be accelerated as charge coating against workpieces 1. The output requirement of the electrical power supply for the described segment between conducting area 2a and conducting area 2b is considerably smaller than the output requirement for maintaining a possibly provided plasma discharge.

In the design according to the statements relating to Fig. 11, the externally supplied plating current corresponds to the charge that is shifted by ion and electron migration between areas 2a and 2b. At least one of the conducting areas 2a or 2b, preferably area 2a acting as workpiece carrier electrode according to Fig. 12a, has a discrete capacitance C_{D1} that is series-connected in front of it. Switching segment S_1 switches the discharge circuit on to the second conducting surface, the furnace in case of evaporation, or the sputter source in case of the sputtering of a conducting or semiconducting material. One provides a current source or a charge source 46a (see also Fig. 11) which, with switching segment S_1 open as one can see in Fig. 12b, is short-circuited with the discrete capacitance C_{D1}, the segment condenser C_1 and the segment impedance Z_P in series and

with switching segment S_1 switched through, as one can see in Fig. 12c via the through-switched discharge current branch.

Here is how this system configuration works:

During ion plating phases, that is to say, during operational phases during which the layer is built up on workpieces 1, the switching segment S_1 is opened. During that phase using source 46a, for example, as shown in Figs. 12b and 12c fashioned as current pulse source, a charge, for example, in the form of a current surge, is driven through the series circuit according to Fig. 12b. The polarity of the imposed charge (current integral) is shown as drawn. This means that the discrete capacitance C_{D1} is charged up and so is the segment condenser C_1, where the field E, building up in the vacuum atmosphere segment, is built up in the direction shown in Fig. 12b as a field that drives the positive ions to workpieces 1. A charge coating is built up on the insulation coating on the workpiece, that is to say, on the latter's nonconducting or poorly conducting surface, which charge coating corresponds to the current i that has flown through during this plating phase.

This shows that the quantity of charge imposed by means of source 46a at least approximately corresponds to the charge coating applied upon workpieces 1 during the plating phase. By changing the externally imposed charge during the plating

phases, one can thus alter the charge coating and thus also the layer buildup rate.

After or between these plating phases, switching segment S_1 is closed in the manner described until then.

As described earlier, discrete capacitances, provided in the discharge circuit, act also briefly upon C_{D1} in the known manner as a short-circuit. When switching segment S_1 is closed, the configuration shown in Fig. 12c is generated on mutually parallel connected elements, that is to say, condenser C_1 and capacitance C_{D1} are charged in a rectified manner, as shown, as a result of which, the discharge procedure of the discrete capacitance C_{D1} now accelerates the discharge or transfer procedure of condenser C_1. The time constant of the discharge procedure is given by the series connection of the two capacitive elements so that by choosing the capacitance value of capacitance C_{D1} as being considerably larger than the capacitance value of condenser C_1, the time behavior of the discharge procedure will essentially be determined by C_1 and impedance Z_P.

The initial charge, applied upon C_{D1}, essentially is the /17 same as the (series circuit) applied upon C_1 so that the discharge procedure is accelerated by which process the voltages in the parallel circuit are brought to equal values.

One can readily see that after the fading of the discharge procedure, the voltages on C_{D1} and C_1 are rectified in a diametrically opposed fashion (parallel circuit).

As explained above during the discharge procedure, essentially only the charge coating of the ions is neutralized and the material coating with ion particles is not changed; therefore, essentially there is no change on the layer that has already been built up during the discharge cycle.

Fig. 12a already shows a development of this preferred process variant, especially for ion plating. Accordingly, once again as described, the discharge current is measured, it is possibly converted in an analog/digital manner on converter 34 and it is stored in memory unit 30 as ACTUAL current. The memory constant in memory unit 30, acting as intermediate memory, is compared in comparison unit 38 with the discharge REQUIRED curve stored in advance in the REQUIRED value memory 40 or it is compared to a characteristic magnitude of same.

Characteristic ACTUAL/REQUIRED behavior differences Δ are determined by analysis unit 42, possibly considering the C_1 values, which change with changing time constants. Using the analysis result by way of regulation, one can so act upon source 46a that the measured ACTUAL discharge behavior or its characteristic parameters will correspond to those of the REQUIRED discharge behavior. In that way, it is possible by

influencing the charge coating of workpieces 1 during the plating phases to master the layer buildup and thus to neutralize the charge coating that becomes dangerous with regard to sparkovers.

Fig. 13 shows a development or a simple embodiment of the technique shown with reference to Fig. 12; it indicates that the invention is now implemented in accordance with its combined aspect as described in Fig. 4. The conditions in vacuum receptacle 3 are as illustrated and described in Fig. 12. This essentially involves how one can make source 46a in the simplest way. For this purpose, one acts upon the network, explained with reference to Fig. 12a, in place of source 46a via a choke L_{66} from the direct-current generator 8.

The direct-current signal generator 8, as shown at U_B is, for example, poled. When switching segment S_1 is closed, then - first of all, without considering unit 56 - there is a current flowing through choke L_{66} via the closed switching segment S_1. The current flowing then is shown in Fig. 13 with the symbol I_1.

If switching segment S_1 is now opened to initiate a plating phase, then over choke L_{66}, there will be a high negative voltage pulse, as is shown schematically at U_{L66} which, by virtue of the now series-connected circuit according to Fig. 12b, drives the charge explained with reference to Fig. 12 through C_{D1} and C_1. After the transient procedure has faded out, then voltage U_B is

applied together on C_1 and C_{D1}. By providing choke L_{66}, one can accelerate the transient procedure during this plating phase. The operating procedure remains essentially the same when choke L_{66} is omitted and when switching segment S_1 is opened and U_B is directly switched to the series circuit of the two capacitive elements C_1 and C_{D1}.

Of course, one must make sure that the same direct-current signal generator 8 on the output side is in a position to hold the voltage and, in the process, quickly to charge the capacitive load.

When choke L_{66} is provided, then one can switch into the discharge circuit, for example, also an electronically variable resistance such as a transistor stage 56, which is adjusted on the output side of analysis unit 42 in accordance with Fig. 12a and which thus [also adjusts] the current flowing through choke L_{66} when switching segment S_1 is closed. By changing this current, one can alter the voltage peak U_{L66} and thus also the time behavior during the transient plating phase. By changing the resistance value on unit 56 between plating phases and discharge phases, unit 56 can be rendered ineffective during the discharge phases (short circuit) or can also be adjusted there to influence the transient time behavior. Furthermore, switching segment S_1 can be combined with unit 56, for example, as transistor control unit.

Naturally, it is readily possible to adjust the resistance value on unit 56 without providing a discharge current measurement with corresponding feedback as explained in Fig. 12a and to operate unit 56, for example, adjusted after prior experiments in a directly synchronized manner with the clock generator 16, 160, as shown in Fig. 12.

As an alternative to the embodiment according to Fig. 13 in a further preferred variant as shown in Fig. 14, one can proceed in such a manner that an extremely efficient and controlled charge transfer will take place during plating phases, that is to say, that there will be a maximum efficient control of charge coating during these phases. For this purpose, looking at the arrangement according to Fig. 12a, there is superposed on the output signal of the direct-current signal generator 8 a voltage signal as illustrated with source 58 whose voltage in the predetermined manner will change over time, that is to say, with predetermined course dU/dt. /18

This source 58 is triggered with the output signal of clock generator 16 or 160 on a trigger input Tr specifically each time during the plating phases, that is to say, when switching segment S_1 is opened. As shown at the bottom in Fig. 14, source 58 can be triggered, depending on the desired layer growth course on the workpieces 1 that are to be coated, [resulting] in a linear or progressive ramp or some other curved shape with

specified layout. Due to the differentiated behavior of the series circuit of the two capacitive elements C_1 and C_{D1}, the current flow then takes place in the known manner, and this also applies to the charge flow per unit of time from the time derivation of the previously mentioned voltage curves. This derivation can be used in terms of the explanations for Fig. 10, source 44, also as adjusting magnitude in a control circuit.

As was discussed earlier in conjunction with Fig. 13, one can thus preset a desired course for the time derivation or, in the context of an adjustment such as via analysis unit 42, it can be so set that a desired charge coating will take place during the plating phases, something that, as mentioned, for example, can be examined in light of the discharge behavior by means of control technology.

Running a plating current setting or control signal is also shown in broken lines in Fig. 13 where, instead of providing an additionally triggered voltage source, the output voltage of the direct current signal generator 8 is varied in synchronism with the output signal of the clock generator 16 or 160 in terms of time.

The process, illustrated with reference to Figs. 11, 12, 13 and 14, can most advantageously be combined especially with an ion-plating method. as a result of which, as mentioned earlier, one gets a novel ion-plating method with the possibility of

depositing conducting layers on nonconducting surfaces and nonconducting layers on conducting surfaces or nonconducting surfaces.

The process, such as it was described for the control of charge coating with reference to Figs. 12 to 14 during the plating phases, is in itself considered as an invention, which naturally can be combined in a most suitable manner with the invention at hand as described.

In all of the embodiment variants of the invention-based process, where according to Fig. 4, starting from a direct-current signal generator 8 via chopper unit 14_s or, as described, via a chopper switch S_1 in accordance with the invention, one acts on a segment between two conducting surfaces 2a, 2b in a vacuum receptacle 3 and where, in the vacuum atmosphere, a plasma discharge PL, as illustrated schematically in Fig. 15, is maintained between electrodes 60a and 60b; one can effectively counter an electrical instability in that, as illustrated, one of the plasma discharge current-conducting electrodes, for example, 60b, is applied to a potential on the discharge current loop. Preferably, for this purpose, one uses one of the plasma electrodes as one of the conducting surfaces used in accordance with the invention as per Fig. 15, for example, area 2b.

This is illustrated by connection 62 in Fig. 15.

Fig. 16 schematically illustrates an additional preferred exemplary embodiment of the invention-based procedure or an invention-based system. A glow discharge is operated in vacuum receptacle 3, for example, between a receptacle wall and a target 64 consisting of conducting or at least semiconducting material. A working gas is piped in with a reactive gas component via a gas supply 18. This, therefore, involves a reactive cathode atomization process. Target 64 can be part of a magnetron atomization source. The works are not entered in Figure 16. They are operated either in a potential floating manner or they are applied on a bias potential, for example, also as was illustrated with reference to Figs. 11 to 14, especially for ion plating.

The glow discharge, operated in the illustrated example between receptacle and target 64 according to the invention, is operated basically according to the procedure given in Fig. 4. According to the explanations given earlier, Fig. 16 requires no further detailed statements. The direct-current signal generator 8 must supply relatively high outputs for the operation of the glow discharge; therefore, when switching segment S_1 is closed by clock generator 160, in other words, in a counterclockwise manner, then a series switching segment S_2 is opened so that the glow discharge current will not flow via the switching segment S_1. In particular, when the direct-current

signal generator 8 has the characteristic of a direct-current source, one can bridge the switching segment S_2 preferably by means of a network, preferably by means of a resistance network, as shown with R in Fig. 16, possibly, however, also by means of an electronically controllable network such as a transistor network.

In that way, one can make sure that, with switching segment S_2 opened, there will be no excessively high-voltage buildup over it.

The above-described measures, such as providing a possibly controlled voltage source U_E that influences the discharge process according to Fig. 7c or steps to measure the discharge procedure and corresponding action on clock generator 160, as described with reference to Fig. 8, are also employed here in a preferred manner. Especially when one proceeds according to Fig. 8 in the case of cathode atomization, for example, according to Fig. 16, one can optimize the system efficiency by adaptively keeping the discharge phases optimally short. /19

In the invention-based ion plating according to Figs. 11 to 14, one preferably alters the signal of the direct-current signal generator 8 with a frequency of 50 kHz to 500 kHz, preferably lat least 90 kHz, particularly preferably at least 100 kHz, something that is equivalent to the operation of the switching segment S_1 with the given frequencies, in other words,

the operation of the clock generator 16, 160 with the specified repetition frequencies. The closing times for switching segment S_1 here are preferably chosen from 50 nsec to 10 µsec, preferably from 0.5 µsec to 2µsec, or from 2µsec to 10µsec, also as a function of the chosen repetition frequency and the treatment procedure to be administered, in particular, the ion-plating process.

During sputtering, such as it was described with reference to Fig. 16 as a preferred exemplary embodiment, one preferably [uses] operating frequencies for switching segment S_1 in accordance with the frequency with which the output signal of the direct-current signal generator 8 is altered, operating with frequencies corresponding to 50 Hz to 1 MHz, preferably 5 kHz to 100 kHz, and particularly preferably with frequencies between 10 kHz and 20 kHz. Here again, as closing time or as discharge time through switching segment S_1, one chooses lengths of 50 nsec to 10 µsec, preferably 0.5 µsec to 2 µsec or from 2 µsec to 10 µsec, coordinated to the particular intended treatment process or the adjusted repetition frequency.

The invention-based process described according to Fig. 16 is particularly suitable for the formation of silicon oxide layers, that is to say, of Si_xO_y. The process is also excellently suited for use with an atomization cathode consisting of a mixture of indium oxide and tin oxide or indium

and tin, which material is atomized in an atmosphere that contains oxygen in order to produce a corresponding coating on workpieces. Naturally, the same device can also be used in order - instead of a target - to etch the surface of workpieces or also only one target with the objective of removing a dirt contamination layer, such as an oxide layer or some other undesirable surface layers.

The reactive cathode atomization process, such as it was described with reference to Fig. 16, can be operated in the oxidic (reactive) or transition mode where, regarding the definition of this operating mode, reference is made to "Reactive DC High-Rate Atomization as Production Process" by S. Schiller et al.; Lecture at the International Conference on Metal Coating, San Diego/Cal., March 1987, Surface and Coating Technology 33 (1987).

It was observed in that connection that, looking at the invention-based cathode atomization process, the transition from the metallic mode into the reactive mode takes place less abruptly than is customary. This means that in the case of the invention-based process, the characteristic line of the in-itself-unstable intermediate area, the intramode, is flatter than usual and that a process working point in this transition area can thus be stabilized in a simpler manner than is done customarily with control technology.

Fig. 17 illustrates another preferred embodiment variant, above all, in conjunction with cathode atomization according to Fig. 16. Of course, this procedure can also be employed in conjunction with ion plating or other invention-based processes of which some examples will also be explained with reference to Fig. 19. Without being restrictive, however, Fig. 17 is illustrated on the basis of the cathode atomization process according to Fig. 16.

Instead of measuring the discharge current, in this case, for example, in the current that supplies the glow discharge, one shows - with a current detector 66 or possibly also optically in the vacuum receptacle - how the origin of stochastic interference discharge manifestations is registered, which are noticed in the form of current peaks in the discharge current I_S. A current measurement device 66 checks the behavior of the measured current on an arc detection unit 68 to see whether the mentioned stochastic discharge manifestations do occur. The output signal of the arc detection unit 68 is supplied to a comparison unit 70. There, one records with what frequency the mentioned discharge manifestations occur and/or with what intensity. The parameter, thus determined, is compared in comparison unit 70 with a REQUIRED parameter that is accordingly predetermined by a predetermination unit 72, and in accordance with the comparison result starting from the output

of the comparison unit 70 via regulator 73, one acts upon the invention-based arrangement shown with a broken line in block 74.

Using regulator 73, one can draw conclusions as to the repetition frequency or the length with which switching segment S_1 is closed, [one can] act via the clock generator 16 or 160, and this is also possible in case of an electrically inactively supplied segment between the conductor surfaces 2a or 2b or, as in this case, during cathode atomization when, in accordance with the invention, the direct current signal generator 8 is provided to operate the mentioned segment.

If, for example, the recorded frequency of occurring discharge manifestations is too high, then the repeat frequency of closing switching segment S_1 is increased and/or the time intervals during which [segment] S_1 closes the discharge circuit is increased. In that case, one can also achieve an optimum efficiency in that the discharge cycles are triggered only as often and as long as this is forced by the ACTUAL arcing behavior. /20

In that way, in particular, the necessary repeat frequency of the discharge or transfer cycles is plotted in accordance with the growth of an insulation coating. This is done along with constant optimization of the system efficiency.

Measurement devices for acquiring the mentioned discharge manifestations in the glow discharge current are known.

Preferably, this procedure is employed in a cathode atomization system, such as it was illustrated in Fig. 16.

Fig. 18 shows another essential embodiment variant of the invention-based procedure, which, in particular, is essential during ion plating according to Figs. 11 to 14. Nevertheless, this procedure is likewise not confined to ion plating. Fig. 18, however, shows - without being in any way restrictive - the further development of ion plating, such as it was presented with reference to Figs. 11 to 14.

In Fig. 18, we use the same reference symbols for parts that were already described in Fig. 12. Ion plating is done in vacuum receptacle 3 in one of the previously described ways, for example, with an evaporation furnace 52 that forms one of the conducting areas 2b. The glow discharge segment or some other plasma discharge segment according to the status with respect to Fig. 12 is no longer entered here. But now several workpiece carrier surfaces $2a_1$, $2a_2$, $2a_3$, ..., $2a_n$ are provided and workpieces 1 that are to be ion plated are deposited there. The particular pairs of invention-based operated conducting areas $2a_x$ and 2b in each case, as is illustrated here only schematically, are operated by an invention-based operating block B_x, as was described with reference to Figs. 11 to 14.

If in such a configuration all provided switching segments S_1, as shown schematically, are switched through simultaneously, then critical energy is withdrawn from the process and especially from the plasma discharge during its plasma operation. This leads to instabilities in process control.

Therefore, according to Fig. 18, there is provided a clock generator 162 and via a time phasing unit 71, such as, for example, via a slide register device, each of the provided units B_1 to B_n are energized cyclically in a time-phased manner. This is illustrated schematically by the time axis t with the phase control pulses. When it is desired to optimize each of the provided segments $2a_x/2b$ in a separately optimized fashion, then clock generator units 16 or 160 are provided separately for each segment according to Fig. 12 and each of the segments is operated in accordance with Figs. 11 to 14, but a synchronization units makes sure that the segments are discharged especially in a time-phased manner via the clock generators 16 or 160, as shown in Fig. 18. Naturally, if necessary, several workpiece carrier areas $2a_x$ can be combined into groups that are operated in a time-phased manner among each other.

It must furthermore be emphasized that using the chopper unit 14 or 14_s, illustrated in Fig. 6 and following figures and described therein, one can convert or retrofit many existing

vacuum treatment systems with direct-current signal generator power supply so that using such systems, one can then operate treatment processes for which until then it was necessary to use other systems, in particular, with other generators according to Fig. 1. In that way, using one and the same system, one can then run procedures, which, on the one hand, can be operated with direct-current power supply, but also those which until then could not be operated with direct-current signal generator power supply, but which can now be used by employing the invention at hand also for such processes.

Some ways of using the invention at hand are illustrated in Fig. 19 in order - without any claim as to completeness and without any restriction - to outline the area in which the process according to the invention would be used. As a result, the expert will readily be able to propose additional invention-based treatment processes or systems in conjunction with the preceding description.

According to Fig. 19, we start with a workpiece 1 consisting of poorly conducting or nonconducting material, in other words, itself forming an insulation coating. In one of the known ways, a plasma discharge PL is generated in vacuum receptacle 3. Workpiece 1 can be subjected to etching treatment, it can be provided with a conducting or possibly a nonconducting coating, be this done by evaporation of conducting

or nonconducting initial materials in a reactive or nonreactive manner, atomization of conducting or semiconducting materials, again reactively or nonreactively. The invention-based operating unit, as was described before, is illustrated schematically with block 5.

Starting with the illustration in Fig. 19, Fig. 19a shows a plasma discharge between plasma discharge electrodes 80a and 80b, which plasma discharge is maintained by a separately provided direct-current or alternating current generator 82. This procedure, for example, involves an ion-plating process. The invention-based operated conducting areas 2a and 2b are operated independently of the plasma discharge. For example, if nonconducting or poorly conducting material is to be atomized in order thereafter in a reactive or nonreactive process to be deposited on workpieces 1, then one can see that generator 82 preferably is made as a high-frequency generator in the known manner (see also Fig. 19f). /21

According to Fig. 19b, plasma discharge PL is maintained by the field of an induction coil 84. Nothing changes with regard to Fig. 19a with respect to the circuitry of the invention-based operated conducting surfaces 2a and 2b. According to Fig. 19c, a plasma discharge is again generated between plasma discharge electrode 80a and 80b; this time, a plasma discharge electrode,

for example, 80b, is employed as one of the invention-based operated conducting surfaces, for example, 2a.

According to Fig. 19d, a workpiece 1 is etched in a plasma discharge section, for example, and in this case the electrodes 80a or 80b simultaneously form the invention-based operated conducting areas 2a and 2b.

With the help of plasma discharge according to Figs. 19a, 19c, a material can be atomized on one of the plasma discharge electrodes in order to be deposited as such on workpiece 1 or after reacting with a working gas or parts of such a gas piped into the vacuum receptacle 3. By the same token, using the illustrated plasma discharge, one can ionize vaporized material in order in terms of ion plating to be deposited on workpieces, be that as such or again after reaction with the reactive gas that was supplied to the vacuum receptacle 3. Basically, the way in which the material sources or the ionization in the vacuum receptacle are done is of subordinate significance as far as the invention is concerned; the essential thing is that workpieces that are coated with insulation according to the invention should be treated in a vacuum atmosphere provided with charge carriers.

One can employ arc vaporization, a so-called rod-feed technique, electron ray evaporation, thermal evaporation and

sputtering, all of this reactively or nonreactively, and one can also use plasma-supported CVD, PECVD.

According to Fig. 19e, a target object (target) 85 in vacuum receptacle 3 consisting of conducting or at least semiconducting material is atomized in the plasma discharge and the atomized material as such or after reaction with a reactive gas in receptacle 3 is deposited as conducting or as nonconducting or poorly conducting layer on workpiece 1. In the first mentioned case, the workpiece has a nonconducting or poorly conducting surface, which can be generated by prior coating or which is inherent in the workpiece material.

Here one can possibly operate both sections according to the invention, that is to say, the plasma discharge segment between the conducting areas 2a and $2b_1$ as well as between 2a and $2b_2$. Generally, one advantageous always operates according to the invention those segments at whose electrodes or leading areas there is no need to fear any deposits of nonconducting or poorly conducting materials or where such materials are provided thereon.

According to Fig. 19f, in a high-frequency plasma discharge, nonconducting or poorly conducting material of a target object 87 is atomized by a cathode and is possibly additionally made to react with a reactive gas piped in through line 18. A layer of nonconducting or poorly conducting material

is deposited on workpiece 1 with the help of ion plating for which purpose, in this case, the workpiece carrier electrode is formed by one of the invention-based operated conducting areas 2b and there is also provided a second conducting area 2a that is separated from the plasma discharge segment.

According to Fig. 19g, a glow discharge is maintained between two plasma discharge electrodes 80a and 80b, for example, and material is evaporated from a furnace, that is, conducting or nonconducting or poorly conducting material. The evaporated material is ionized in the plasma discharge, and by way of ion plating, a conducting or nonconducting or poorly conducting layer is deposited on workpiece 1. This again can involve a reaction process where a reactive gas is supplied to the process through gas feed 18.

Both the glow discharge GL and the segment between the segment between the two conducting areas 2a and 2b are according to the invention again operated with blocks 5 as shown.

Finally, Fig. 19h shows an embodiment variant of the invention similar to Fig. 19g, whereby, however, in this case the plasma discharge for the ionization of the evaporated material is generated by the magnetic field of a winding 91 in receptacle 3.

The examples cited show the expert to what extent the invention at hand can be used.

Examples for Invention-Based Cathode Atomization:

1)

/22

System:	BAS 450 by Balzers AG Company
Cathode:	AK 510 by Balzers AG Company
Magnet system:	MA 525 by Balzers AG Company
Target: S10-2403	Silicon target (5 x 10 inches)
DC power supply:	10 kW
Target substrate area:	70 mm
Rotary basket rotation frequency:	<0.5 Hz
Discharge frequency:	17 kHz
Discharge time:	9 µsec
Discharge voltage:	Short circuit
Effective sputter output:	2 kW
System pressures:	
Ar:	pAr = 8E-3 mbar
O_2:	pO_2 = 2E-3 mbar
DC voltage on target:	
In metal mode:	-668 V
At working point between metal mode and oxide mode:	-340 V
Layer:	SiO_2
Refraction value SiO_2, at λ = 633 nm:	1.47
K-value SiO_2 at λ = 633 nm:	<1E-5

System:	BAK 760 by Balzers AG Company
Cathode:	AK 525 by Balzers AG Company
Magnet system:	MA 525 by Balzers AG Company
Target: S10-3976	Silicon target (5 x 25 inches)
DC power supply:	10 kW
Target substrate area:	60 mm
Rotary basket rotation frequency:	<0.5 Hz
Discharge frequency:	17 kHz
Discharge time:	16 μsec
Discharge voltage:	Short circuit
Effective sputter output:	2 kW
System pressures:	
Ar:	pAr = 8E-4 mbar
O_2:	pO_2 = 2E-5 mbar
DC voltage on target:	
In metal mode:	-660 V
At working point between metal mode and oxide mode:	-550 V
Layer:	284 nm SiO_2
Energy output: (DDR = layer volume per corresponding energy)	DDR(SiO_2) = 44.6 nm mm^2/Ws
Refraction value SiO_2, at λ = 633 nm:	1.47
K-value SiO_2 at λ = 633 nm:	<1E-5

Examples of Invention-Based of Ion Plating

1. Shaping tools are provided with a silicon nitride layer by means of a system structured as shown by the diagram in Fig. 12a in the embodiment variant according to Figs. 15 and 18 by way of a reactive ion-plating process with evaporation of silicon. The resultant corrosion-proof coated molding tools were then once again coated with an additional hard substance layer to make them abrasion-proof.

For this purpose, titanium carbonitride was used for aluminum beading wheels as shaping tools and titanium nitride was used for injection molding forms for polyvinylchloride, while chrome nitride layers were used for metal die-casting forms.

Known ion-plating methods were primarily used.

It was only when the invention-based process was used, when a direct voltage was applied and when there was a discharge with predetermined frequency that, on the one hand, the problems resulting on the basis of the electrically insulating substrate were solved; on the other hand, and especially also only then was it possible to achieve adequate adhesion of the abrasion-proof layer on the silicon nitride layer. Tools fit for use could be made only by employing the invention-based procedure for ion plating. /24

2. An attempt was made to coat indexable inserts with physical coating methods in the known manner. For this purpose, aluminum and chrome were evaporated simultaneously from a furnace. It was found that the layers, of course, offered adequate hardness, but that in some applications, the wear-and-tear resistance was inadequate, especially those with particularly high abrasion stress.

An analysis of the layer in the scanning electron microscope showed that the layers were not adequately compact.

Thereupon, the same coating was made according to the invention by way of the described ion-plating method, as a result of which, as desired, there was an increase in the wear-and-tear resistance on the indexable inserts.

We proceeded as illustrated in Fig. 18 for series production according to both examples with more than two substrate carriers. It was found that a minimum interval of 10 nsec between discharge cycles on the individual workpiece carriers is necessary. Operation with intervals of > 200 nsec between discharge cycles of individual workpiece carriers proved to be particularly stable.

Using this method, it was possible to ion plate workpieces on a large number of substrate carriers, according to the tests, actually, 12, in the invention-based manner; here, in the coating of the indexable inserts, their abrasion wear-and-tear resistance corresponded to that of the indexable inserts with layers that had been separated according to the state of the art by means of high-temperature CVD methods.

Generally, workpieces that were ion-plated according to the invention, displayed higher viscosity than workpieces that were coated with high-temperature CVD methods, this being said on the basis of the invention-based low treatment temperatures. The high viscosity of the invention-based coated indexable inserts,

as described above, will make it possible to work by way of uninterrupted cutting operation.

Here are the additional essential advantages deriving from the invention:

1. In case of cathode atomization:

In addition to the advantages already listed in the specification, there is the fact that:

- the efficiency deriving from the applied layer volume per electrical energy expended is increased compared to previously known methods,

- the transition from the metallic mode to the reactive or oxidic mode is flatter, which means that it is easier to stabilize a process working point in the transition mode by way of process control.

2. In the case of invention-based ion plating:

In addition to the advantages listed in the prior specification, there is the fact that:

- the adhesion properties of invention-based ion-plated layers are improved,

- the compactness of invention-based ion-plating layers is increased and thus their wear-and-tear resistance is also increased,

- the treatment temperature of the substrates to be coated can be kept low as is customary in ion plating, but, as a

result, the ion plating was employed there by virtue of its invention-based implementation where, until then, one usually employed high-temperature CVD methods; the viscosity of the invention-based coated substrates can be increased considerably when compared to those that are coated right away with high-temperature CVD.

Important Characteristics and Characteristic Combinations of the Invention

I. Method for workpiece treatment in a vacuum atmosphere where, between at least two conducting areas that are in active connection with the vacuum atmosphere, where one of the areas has a partial coating - "insulation coating" - with nonconducting or poorly conducting material and where charge carriers are present in the atmosphere, where the output signal of a direct-current signal generator is applied to the areas, and during treatment in a targeted manner as often and/or as long as required by the charge coating conditions, an additional signal, deviating from the mentioned output signal, is applied to the areas and, in the process, averaged over the treatment time, the mentioned output signal remaining applied considerably longer than the other signal.

II. Process for workpiece treatment in a vacuum atmosphere where charge carriers are present in a vacuum atmosphere in at least two conducting areas where at least one has at least a

partial coating - "insulation coating" - with poorly or nonconducting material that is in contact with the vacuum atmosphere, where the area, at predeterminable or predetermined times, is at least briefly short-circuited and/or is connected via charge source by means of a discharge or transfer current branch. /25

III. Process according to the Characteristic Sets I and II, where, furthermore, the short-circuiting and/or the application of the charge source is done in time intervals during which the additional signal is applied and where at least the area that is coated according to Claim 1 will be the area that is coated according to Claim 2.

IV. Process, preferably according to one of the Characteristic Sets, such as according to one of Characteristic Sets I or III, where, furthermore, the additional signal is generated by chopping the output signal of the generator.

V. Process, preferably according to at least one of the Characteristic Sets, such as according to Characteristic Set IV, whereby, furthermore, the additional signal is given by parallel chopping of the mentioned output signal.

VI. Process, preferably according to at least one of the Characteristic Sets, such as according to one of Characteristic Sets I to V, where at least one workpiece:

a) has a surface consisting of nonconducting or poorly conducting material as insulation coating and/or

b) with a layer consisting of poorly conducting or nonconducting material as insulation coating, which is coated by means of the treatment method

and the workpiece is deposited on one of the mentioned conducting areas.

VII. Process, preferably according to at least one of the Characteristic Sets, such as according to Characteristic Set VI, where a layer of conducting material is further deposited on the surface made of nonconducting or poorly conducting material and insulation coating.

VIII. Process, preferably according to at least one of the Characteristic Sets, such as according to one of Characteristic Sets I to VII, where the workpiece treatment furthermore involves ion-plating treatment.

IX. Process, preferably according to at least one of the Characteristic Sets, such as according to one of Characteristic Sets I to VIII, where furthermore:

a) a conducting material, whereupon the mentioned insulation coating is already present regardless of the process or is in the course of being applied by the method, is atomized as source material for a coating method or is vaporized and/or

b) a nonconducting or poorly conducting material is vaporized as source material that forms the insulation coating for a coating procedure

and the material forms one of the areas or is deposited on a conducting area of the areas mentioned.

X. Process, preferably according to at least one of the Characteristic Sets, such as according to one of Sets I to IX, where, furthermore, the process comprises a PVD treatment method or a reactive PVD method or a plasma-supported CVD method.

XI. Process, preferably according to at least one of the Sets, such as according to one of Sets I to X, where, furthermore, the plasma is generated in a vacuum atmosphere.

XII. Process, preferably according to at least one of the Sets, such as according to Set XI, where, furthermore, the plasma is fed from one of the mentioned areas.

XIII. Process, preferably according to at least one of the Sets, such as according to Set XI, where, furthermore, one of the electrodes for which the plasma is being fed is deposited on potential of one of the mentioned areas.

XIV. Process, preferably according to at least one of the Sets, such as according to one of Sets II to XIII, where, furthermore, the discharge or transfer behavior in the mentioned circuit is measured.

XV. Process, preferably according to at least one of the Sets, such as according to Set XIV, where, furthermore, one can conclude as to the thickness of the insulation coating on one of the mentioned areas from the measured discharge or transfer behavior.

XVI. Process, preferably according to at least one of the Sets, such as according to Set XIV, where, furthermore, one can draw conclusions as to the charge coverage on the insulation coating from the measured discharge or transfer behavior.

XVII. Process, preferably according to at least one of the Sets, such as according to one of Sets II to XVI, where, furthermore, one measures the buildup of charge coverage on the insulation coating.

XVIII. Process, preferably according to at least one of the Sets, such as according to one of Sets XIV to XVII, where, furthermore, the measured discharge or transfer behavior is compared to a REQUIRED behavior and the function of the comparison result, the charge coverage by means of external charge feeding and/or the change of the discharge or transfer cycle frequency and/or the change of the discharge or transfer cycle length is so adjusted that the resultant measured discharge or transfer behavior will be at least approaching the REQUIRED behavior.

XIX. Process, preferably according to at least one of the Sets, such as according to one of Sets XIV to XVIII, where, furthermore, one observes spontaneous discharge manifestations caused by the charge coverage, depending on the manifestation frequency and/or the type of manifestation, this coverage being so controlled or regulated by external charge feed and/or change of the discharge or transfer cycle frequency and/or the change of the discharge or transfer cycle length that one can achieve a desired behavior with regard to the mentioned spontaneous discharges. /26

XX. Process, preferably according to at least one of the Sets, such as according to one of Sets XIV to XIX, where, furthermore, when the measured discharge or transfer procedure has reached a predetermined state, that procedure is broken off.

XXI. Process, preferably according to at least one of the Sets, such as according to one of Sets II to XX, where, furthermore, during phases between discharge or transfer cycles, a charge coverage buildup is controlled by external feeding a charge upon the areas to be coated or the insulation-coated area.

XXII. Process, preferably according to at least one of the Sets, such as according to Set XXI, where, furthermore, the charge coverage buildup is controlled as a layer buildup upon at least one workpiece during the process of ion plating.

XXIII. Process, preferably according to at least one of the Sets, such as according to one of Sets I to XXII, where, furthermore, the workpiece surface, itself acting as insulation coating, is poorly or nonconducting and is coated by ion plating and/or the workpiece surface is coated with a layer consisting of poorly or nonconducting material as insulation coating by means of ion plating, and in the process, a workpiece carrier surface is one of the mentioned conducting areas and the carrier surface is series-connected with a capacitive element in the discharge circuit in such a way that, during the plating phases, this capacitance and the condenser, formed by at least one insulation coating on the workpiece, appear in series, parallel in discharge cycles, and that, during plating phases, the series circuit is so built up that there is an essential predeterminable ion coating upon the workpieces.

XXIV. Process, preferably according to at least one of the Sets, such as according to Set XXIII, where, furthermore, during plating phases, a predetermined or predeterminable charge is driven through the series circuitry of capacitance and condenser and the coating with charge carriers on the workpiece surface is thus controlled.

XXV. Process, preferably according to at least one of the Sets, such as according to Set XXIV, where, furthermore, the charge is driven by way of the series circuitry by applying a

voltage with predetermined or predeterminable course of its change in terms of time.

XXVI. Process, preferably according to at least one of the Sets, such as according to one of Sets XXIII to XXV, where, furthermore, the series circuit is charged by means of an inductive voltage increase in the series circuit.

XXVII. Process, preferably according to at least one of the Sets, such as according to one of Sets XXIII to XXVI, where, furthermore, the series circuit is charged during the plating phases with a ramp voltage essentially with a constant current and where thus an essentially constant charge coverage rate is generated.

XXVIII. Process, preferably according to at least one of the Sets, such as according to one of Sets I to XXVII, where, furthermore, two or more pairs of areas are provided and are operated in time-phased manner per pairs or per pair groups with a direct-current generator and/or with a discharge or transfer current branch.

XXIX. Process, preferably according to at least one of the Sets, such as according to one of Sets I to XXVIII, where, furthermore, workpieces are treated by ion plating of at least two provided pairs or groups of areas and where the pairs or groups are subjected to discharge cycles in a time-phased manner.

XXX. Process, preferably according to at least one of the Sets, such as according to one of Sets XXIII to XXIX, where, furthermore the charging procedure is measured, it is compared to a REQUIRED procedure, and by means of variation of charging of the series circuit in plating phases is a function of the resulting comparison, whereby the charge coverage by means of ions on the workpiece and thus possibly considering any changes in the condenser is determined from changes in the time constant during the discharge procedure where the measured discharge procedure is at least adjusted to the REQUIRED procedure.

XXXI. Process, preferably according to at least one of the Sets, such as according to one of Sets XXIII to XXX, where, furthermore, the discharge procedure is accomplished with a repetition frequency of 50 kHz to 500 Hz, preferably at least 90 kHz, preferably at least 100 kHz.

XXXII. Process, preferably according to at least one of the Sets, such as according to one of Sets XXIII to XXXI, where, furthermore, by means of ion plating on at least one workpiece, at least one corrosion-proof and/or at least one wear-and-tear-proof layer is generated, for example, a nonconducting or poorly conducting first layer as corrosion protection layer and a conducting second layer as wear-and-tear protection layer or further combinations of layers as well as layer systems with two or more layers.

XXXIII. Process, preferably according to at least one of the Sets, such as according to one of Sets I to XXI, where, furthermore, in the vacuum atmosphere, a conducting material is atomized by means of a plasma discharge, which is maintained between the material to be atomized and a counterelectrode, while the atomized material is made to react with reactive gas piped into the vacuum atmosphere for the formation of a nonconducting or poorly conducting material connection in the plasma and where, via the plasma discharge segment, the control discharge current as well as via - connected in series - the direct-current signal generator and an interruption switching segment [are generated], whereby the latter are triggered intermittently and the through-switching of the discharge current circuit [are performed]. /27

XXXIV. Process, preferably according to at least one of the Sets, such as according to Set XXXIII, where, furthermore, especially in case of the current source characteristic of the generator, the switching section is bridged by means of a network, preferably a passive, preferably a resistance network [sic].

XXXV. Process, preferably according to at least one of the Sets, such as according to one of Sets XXXIII or XXXIV, where, furthermore, the reactive cathode atomization process is operated in the oxidic or in the transition mode.

XXXVI. Process, preferably according to at least one of the Sets, such as according to one of Sets XXXIII to XXXV, where, furthermore, silicon is cathode atomized and is made to react with oxygen to form a silicon oxide.

XXXVII. Process, preferably according to at least one of the Sets, such as according to one of Sets XXXIII to XXXVI, where, furthermore, dielectric or poorly or semiconducting layers on a metal base are generated.

XXXVIII. Process, preferably according to at least one of the Sets, such as according to one of Sets I to XXI, XXXIII to XXXVII, where, furthermore, the signal is applied with a frequency corresponding to 50 Hz to 1 MHz, preferably corresponding to 5 kHz to 100 kHz, especially preferably to 10 kHz to 20 kHz.

XXXIX. Process, preferably according to at least one of the Sets, such as according to one of Sets I through XXXVIII, where, furthermore, the additional signal in each case is applied with lengths of 50 nsec to 10 μsec, preferably from 0.5 μsec to 2μsec or from 2 μsec to 10 μsec.

XL. Process for the control of charge coverage on a surface of a part, which surface is formed by a nonconducting or poorly conducting portion of the part or a nonconducting or poorly conducting coverage of the part, whereby the part is connected with a conducting area and the surface lies in a vacuum

treatment atmosphere with charge carriers, whereby, via the conducting area, the charge in a controlled manner - especially in a plasma treatment method - drives the part with the surface of a segment of the vacuum atmosphere and another conducting area that is in active connection with the vacuum atmosphere [sic].

XXXXI. Vacuum treatment system with a vacuum receptacle (3) within which there is a carrier arrangement to receive the workpiece in which system an electrical signal generator is applied to at least two conducting (2a, 2b) areas that are in active connection with the atmosphere in the vacuum receptacle, whereby the signal generator comprises a direct-current signal generator (8) as well as a unit (12, 14; 14s; S_1) that is series connected after it by means of which the output signal of the generator (8) is changed so as to form the signal that is applied to the conducting areas (2a, 2b), whereby the unit is so controlled or can be so controlled (16, 160) that in a predetermined or predeterminable time sequence and for predetermined or predeterminable time intervals, it alters the signal of the direct-current signal generator (8).

XXXXII. Vacuum treatment system with a vacuum receptacle (3) in which there is a carrier arrangement to receive the workpiece, furthermore, with means to generate charge carriers in the receptacle, whereby two conducting areas (2a, 2b) are in

active connection with the atmosphere in the receptacle (3) [and] are connected with each other via a controlled discharge or transfer current branch (14, 14s, S_1).

XXXXIII. Vacuum treatment system according to Sets XXXXI and XXXXII, where, furthermore, the time sequence and the control of the discharge or transfer current branch is synchronized and at least one of the conducting areas according to Set XXXXI is one of those according to Set XXXXII.

XXXXIV. Vacuum treatment system, preferably according to at least one of the Sets, such as according to one of Sets XXXXI to XXXXIII, where, furthermore, the two conducting areas (2a, 2b) are connected via a control short-circuit switching unit (14s, S_1).

XXXXV. Vacuum treatment system, preferably according to at least one of the Sets, such as according to Set XXXXIV, where, furthermore, the short-circuit switching unit (S_1) forms both the unit (12, S) that is series-connected after the direct-current signal generator (8) as well as the control unit (14) for the discharge or transfer current branch.

XXXXVI. Vacuum treatment system, preferably according to at least one of the Sets, such as according to one of Sets XXXXI to XXXXV, where, furthermore, one of the conducting areas (29) is an area for workpiece reception or an area (52, 2b) to receive a

source material, which source material is used during the coating of at least one workpiece (1). /28

XXXXVII. Vacuum treatment system, preferably according to at least one of the Sets, such as according to one of Sets XXXXI to XXXXVI, where, furthermore, one of the conducting areas (2a) is a workpiece reception surface and the system is an ion-plating system.

IIL. Vacuum treatment system, preferably according to at least one of the Sets, such as according to one of Sets XXXXI to XXXXVII, where, furthermore, there is provided a target object (64), which is atomized, and where one of the conducting areas (2b) is in active connection with the vacuum atmosphere via the target object (64).

IL. System, preferably according to at least one of the Sets, such as according to Set IIL, where, furthermore, the target object is a part of a magnetron device.

L. System, preferably according to at least one of the Sets, such as according to one of Sets XXXXI to IL, where, further means (52, 50; 3, 64) are provided for the generation of a plasma discharge (PL).

LI. System, preferably according to at least one of the Sets, such as according to one of Sets XXXXI to L, where at least one electrode pair is provided to generate a plasma

discharge in the receptacle and preferably at least one of the electrodes (64) is one of the conducting areas (2b).

LII. System, preferably according to at least one of the Sets, such as according to one of Sets XXXXI to LI, where at least three ($2a_1$, $2a_2$, 2b) of the mentioned conducting areas are provided and where, associated with them, is, in pairs, one generator each (8) according to Claim 41 and/or one current branch according to Claim 42 that are triggered in a time-phased manner via a time control unit (70).

LIII. System, preferably according to at least one of the Sets, such as according to Set LII, where, furthermore, several groups of the conducting areas are triggered by the time-control unit in a time-phased manner.

LIV. System, preferably according to at least one of the Sets, such as according to one of Sets XXXXI to LII, where, furthermore, a gas feed (18) empties into the vacuum receptacle, which gas feed is connected with the supply of reactive gas.

LV. System, preferably according to at least one of the Sets, such as according to one of Sets XXXXI to LIV, where, furthermore, it is a PVD system or a reactive PVD system or a system for plasma-support CVD or a system for thermal CVD with a device for the ionization of gas portions in the receptacle.

LVI. System, preferably according to at least one of the Sets, such as according to one of Sets XXXXI to LV, where,

furthermore, there is provided a low-voltage glow discharge section (50, 52), preferably with a glow cathode (50).

LVII. System, preferably according to at least one of the Sets, such as according to one of Sets XXXXI to LVI, where at least two electrodes (60a, 60b) are provided to generate a plasma (PL) in the vacuum receptacle (3), while one of the electrodes (60b) is applied to the potential of one of the mentioned conducting areas (62).

LVIII. System, preferably according to at least one of the Sets, such as according to one of Sets XXXXI to LVII, where, furthermore, the controlled discharge or transfer current branch is capacitive (C_1, C_D, C_{D1}) in the fully controlled state.

LIX. System, preferably according to at least one of the Sets, such as according to one of Sets XXXXI to LVIII, where, furthermore, a charge memory (C_D, 20, C_{D1}) and/or a voltage source (U_E) is connected into the discharge current branch.

LX. System, preferably according to at least one of the Sets, such as according to one of Sets XXXXI to LIX, where, furthermore, a measurement device (24; 32; 66) is provided on the controlled discharge or transfer current circuit to measure a signal that is representative of the current in the mentioned branch.

LXI. System, preferably according to at least one of the Sets, such as according to Set LX, where, furthermore, the

output signal of a measurement device is fed back upon a control member or unit (30; 16, 160; 56; 73) for the control of the controlled discharge or transfer circuit.

LXII. System, preferably according to at least one of the Sets, such as according to Set LX or LXI, where, furthermore, the output of the measurement device acts upon a threshold value sensitive unit (26) with preferably adjustable threshold value (W) whose output acts upon a control input (30, R) for the controlled discharge or transfer current branch.

LXIII. System, preferably according to at least one of the Sets, such as according to one of Sets LX to LXII, where, furthermore, the output of the measurement device, possibly via an analog/digital converter (34), is supplied to an ACTUAL value memory unit (36) whose output, together with the output of a REQUIRED value memory unit (40), is supplied to a comparator unit (38) and that the output of the comparator unit (38), possibly via an analysis unit (42), acts upon a control input for the control discharge or transfer current branch.

LXIV. System, preferably according to at least one of the Sets, such as according to one of Sets XXXXI to LXIII, where, furthermore, a controlled or controllable charge source (20, 22, 44; 58, C_{D1}) acts upon the segment between two conducting areas (2a, 2b), especially during time phases in which the controlled

discharge or transfer current branch is controlled in an interrupted fashion or is controlled in a high-ohmic manner. /29

LXV. System, preferably according to at least one of the Sets, such as according to one of Sets XXXXI to LXIV, where, furthermore, at least one of the electrically conducting areas (2a) has series-connected in front of it in the current branch a capacitive element (C_{D1}) and means are provided (46, 46a, 58) in order in a controlled manner to charge the series-connected segment with the capacitive element (C_{D1}) between the conducting areas (2a, 2b), whereby the capacity element is positioned parallel with the segment when the current branch (S_1) is switched through.

LXVI. System, preferably according to at least one of the Sets, such as according to one of Sets XXXXI to LXV, where, furthermore, at least one of the areas (2a) has series-connected in front of it a capacitive element (C_{D1}) and where, in case of a current branch that is energized or interrupted in a high-ohmic fashion, the segment between the two conducting areas (2a, 2b) is connected in series with the capacitive element and, for this purpose, in series, a voltage source (58) is placed, which produces a time-controlled or controllable changing output signal (dU/dt) in such a way that a controlled or controllable current will flow through the series circuit as a function of the time change of the voltage source output signal.

LXVII. System, preferably according to at least one of the Sets, such as according to one of Sets LXV to LXVI, where, furthermore, the means for charging the mentioned series circuit comprise inductive means (L_{66}).

LXVIII. System, preferably according to at least one of the Sets, such as according to one of Sets XXXXI to LXVII, where, furthermore, the system is an ion-plating system and one of the conducting areas (2a) forms carriers for workpieces (1), where via a capacitive element (C_{D1}) and a controlled switching segment (S_1), a discharge current branch is formed via the conducting areas (2a, 2b), while the direct-current signal generator (8) is positioned parallel to the switching section (S_1) and preferably a charge source (58, C_{D1}), in series, cooperates with the mentioned section (S_1) and the capacitive element (C_{D1}) or with the latter (C_{D1}) forms a charge source, which charge source is so synchronized with the operation of the switching section (S_1) that, when the switching section (S_1) is interrupted, a predetermined or predeterminable charge current will flow via the section between the conducting areas (2a, 2b).

LXIX. System, preferably according to at least one of the Sets, such as according to Set LXVIII, where, furthermore, several of the areas ($2a_x$) acting as workpiece carriers are provided, while associated through them, there is one switching section (S_1) each to form a discharge current branch, just as for

one capacitive element (C_{D1}) each and preferably one charge source (58, C_{D1}) each or one capacitive element (C_{D1}) each a charge source is formed, and that a time control unit (162, 71) is provided, which triggers the switching section (S_1) in a time-phased manner.

LXX. System, preferably according to at least one of the Sets, such as according to one of Sets XXXXI to LXIX, where, furthermore, in the system, there is provided an atomization target object (64), whereupon there is provided one of the conducting areas (2b) and that the two areas (2a, 2b) are connected via a controlled switching section (S_1) to form a discharge current branch and, furthermore, via a series switching section (S_2), there is provided a direct-current signal generator (8) and, in the process, the switching sections (S_1, S_2) are intermittently operated by a time-controlled unit (160).

LXXI. System, preferably according to at least one of the Sets, such as according to Set LXX, where, further detection means for interference discharges (66) are provided in receptacle (3), whose output signal is conducted to a comparison unit (70) to which is supplied the output signal from a REQUIRED value predetermination unit (72) and where the output signal of the comparison unit (70) acts upon a control unit, preferably upon a time-controlled unit (16, 160), which triggers the intermittent operation of the switching sections (S_1) [sic].

LXXII. Use of the system according to at least one of Sets XXXXI to LXXI for the production of optical layers.

LXXIII. Use according to Set LXXII, where, furthermore, the system has at least one atomization target object (64).

LXXIV. Use of the system according to at least one of Sets XXXXI to LXXI for the production of hard substance and/or wear-and-tear protection layers.

LXXV. Use according to Set LXXIV, where the system, furthermore, is an ion-plating system.

Claims

1. Process for workpiece treatment in a vacuum atmosphere where at least two conducting areas that are in active connection with the vacuum atmosphere and where at least one electrical signal is applied [upon] one of them via at least one partial coverage - "insulation coating" - with nonconducting or poorly conducting material and charge carriers are present in the atmosphere, characterized in that the output signal of a direct-current signal generator is applied to the areas and during treatment, as often and/or as necessary, such as this is required for charge coverage conditions, an additional signal, deviating from the mentioned output signals, is applied to the areas and, in the process, averaged over the treatment time, the

mentioned output signal remaining applied considerably longer than the other signal. /30

2. Process for workpiece treatment in a vacuum atmosphere in which process charge carriers are present in the vacuum atmosphere and at least two conducting areas of which at least one is connected with the vacuum atmosphere via a partial coverage - "insulation coating" - with poorly or nonconducting material, characterized in that the areas, at least for a short time, that is, predeterminable or predetermined time intervals, are short-circuited and/or are connected via a charge source, via a discharge or transfer current branch.

3. Process according to Claims 1 and 2, characterized in that the short-circuiting and/or the application of the charge source is done at time intervals during which the additional signal is applied and at least the area that is coated according to Claim 1 is the area that is coated according to Claim 2.

4. Process, preferably according to at least one of the claims, such as according to one of Claims 1 or 3, characterized in that the additional signal is generated by chopping the output signal of the generator.

5. Process, preferably according to at least one of the claims, such as according to Claim 4, characterized in that

the additional signal is obtained by parallel chopping of the mentioned output signal.

6. Process, preferably according to at least one of the claims, such as according to one of Claims 1 to 5, characterized in that the workpiece treatment is ion-plating treatment.
7. Process, preferably according to at least one of the claims, such as according to one of Claims 1 to 6, characterized in that a plasma is generated in the vacuum atmosphere.
8. Process, preferably according to at least one of the claims, such as according to Claim 7, characterized in that the plasma is fed on one of the mentioned areas.
9. Process, preferably according to at least one of the claims, such as according to one of Claims 2 to 8, characterized in that the discharge or transfer behavior in the mentioned circuit is measured.
10. Process, preferably according to at least one of the claims, such as according to Claim 9, characterized in that the measured discharge or transfer behavior is compared with a REQUIRED behavior and, as a function of the result of the comparison, the charge coverage is so adjusted by means of external charge feed and/or change of the discharge or transfer cycle frequency and/or change of the

discharge or transfer cycle length that the resultant measured discharge or transfer behavior will be at least near the REQUIRED behavior.

11. Process, preferably according to at least one of the claims, such as according to one of Claims 9 or 10, characterized in that one observes spontaneous discharge manifestations brought about by the charge coverage and, depending on the manifestation frequency and/or type of manifestation, this coverage is so controlled or regulated by external charge feeding and/or change of the discharge or transfer cycle frequency and/or change of the discharge or transfer cycle length that one can achieve a desired behavior regarding the mentioned spontaneous discharges.

12. Process, preferably according to at least one of the claims, such as according to one of Claims 9 to 11, characterized in that when the measured discharge or transfer procedure has reached a predetermined state, this procedure is broken off.

13. Process, preferably according to at least one of the claims, such as according to one of Claims 2 to 12, characterized in that during phases between discharge or transfer cycles, a charge coverage buildup is controlled by externally feeding a charge upon the areas to be covered or the insulation-coated area.

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14. Process, preferably according to at least one of the claims, such as according to Claim 13, characterized in that the charge coverage buildup is controlled as a layer buildup upon at least one workpiece during ion plating.

15. Process, preferably according to at least one of the claims, such as according to one of Claims 1 to 14, characterized in that the workpiece surface, itself acting as insulation coating, is poorly conducting or nonconducting and is coated by means of ion plating and/or the workpiece surface is coated with a layer consisting or poorly or nonconducting material as insulation coating by means of ion plating and that, in the process, a workpiece carrier area is one of the mentioned areas and that a capacitive element is series-connected with the carrier area in the discharge circuit in such a way that during plating phases, this capacitance and the condenser, formed by at least one insulation coating on the workpiece, will appear in series, parallel in discharge cycles, and that, during plating phases, the series circuit is so charged that there will be an essentially predeterminable ion coating on the workpieces.

16. Process, preferably according to at least one of the claims, such as according to Claim 15, characterized in that during plating phases, a predetermined or

predeterminable charge is driven through the series circuit of capacitance and condenser and that the coverage with charge carriers is thus controlled on the workpiece surface.

17. Process, preferably according to at least one of the claims, such as according to Claim 16, characterized in that the charge is driven by the locking-on of a voltage with predetermined or predeterminable course of its change in terms of time by means of the series circuit.

18. Process, preferably according to at least one of the claims, such as according to one of Claims 15 to 17, characterized in that the charging of the series circuit is performed by means of an inductive voltage rise in the series circuit.

19. Process, preferably according to at least one of the claims, such as according to one of Claims 15 to 18, characterized in that the charging of the series circuit takes place during the plating phases with a ramp voltage essentially with a constant current and that thus an essentially constant charge coverage rate is generated.

20. Process, preferably according to at least one of the claims, such as according to one of Claims 1 to 19, characterized in that two or more pairs of areas are provided, that, per pair or per pair groups, are operated

in a time-phased manner with a direct-current generator and/or with a discharge or transfer current branch.

21. Process, preferably according to at least one of the claims, such as according to one of Claims 1 to 20, characterized in that workpieces are treated by ion plating on at least two provided pairs or groups of areas and that the pairs or groups are subjected to time-phased discharge cycles.

22. Process, preferably according to at least one of the claims, such as according to one of Claims 1 to 13, characterized in that in the vacuum atmosphere, a conducting material is atomized by means of a plasma discharge, which is maintained between the material to be atomized and a counterelectrode, that the atomized material is made to react with a reactive gas piped into the vacuum atmosphere for the formation of a nonconducting or poorly conducting material connection in the plasma and that, above the plasma discharge section, the controlled discharge current circuit as well as above that, in series, the direct-current signal generator and an interruption switching section are triggered, whereby the latter is triggered intermittently and the through-connection of the discharge circuit [sic].

23. Vacuum treatment system with a vacuum receptacle (3), arranged therein a carrier arrangement for workpiece reception, in which system an electrical signal generator is applied to at least two conducting (2a, 2b) areas that are in active connection with the atmosphere in the vacuum receptacle, characterized in that the signal generator comprises a direct-current signal generator (8) as well as a unit (12; 14; 14s, S_1) that is series-connected after it by means of which the output signal of the generator (8) is changed so as to form the signal applied to the conducting areas (2a, 2b), whereby the unit is so controlled or can be so controlled (16, 160) that it will change the signal of the direct-current signal generator (8) in a predetermined or predeterminable time sequence and predetermined or predeterminable time intervals. /32

24. Vacuum treatment system with a vacuum receptacle (3) containing a carrier arrangement for workpiece reception, furthermore, with means for the generation of charge carriers in the receptacle, characterized in that two conducting areas (2a, 2b), which are in active connection with the atmosphere on receptacle (3), are connected with each other via a controlled discharge or transfer current branch (14, 14s, S_1).

25. Vacuum treatment system according to Claims 23 and 24, characterized in that the time sequence and the control of the discharge or transfer current branch are synchronized and at least one of the conducting areas according to Claim 23 is one of those according to Claim 24.

26. Vacuum treatment system, preferably according to at least one of the claims, such as according to one of Claims 23 to 25, characterized in that the two conducting areas (2a, 2b) are connected via a controlled short-circuit switching unit (14s, S_1).

27. Vacuum treatment system, preferably according to at least one of the claims, such as according to Claim 26, characterized in that the short-circuit switching unit (S_1) forms both the unit (12, S) that is series-connected after the direct-current signal generator (8) and the control unit (14) for the discharge of transfer current branch.

28. Vacuum treatment system, preferably according to at least one of the claims, such as according to one of Claims 23 to 27, characterized in that one of the conducting areas (29) is an area to receive workpieces or an area (52, 2b) for the reception of a source material, which source material is used during the coating of at least one workpiece (1).

29. Vacuum treatment system, preferably according to at least one of the claims, such as according to one of Claims 23 to

28, characterized in that one of the conducting areas (2a) is a workpiece receiving area and that the system is an ion-plating system.

30. Vacuum treatment system, preferably according to at least one of the claims, such as according to one of Claims 23 to 29, characterized in that there is provided a target object (64) that is atomized and that one of the conducting areas (2b) is in active connection with the vacuum atmosphere via the target object (64).

31. System, preferably according to at least one of the claims, such as according to one of Claims 23 to 30, characterized in that means (52, 50; 3, 64) are provided for the generation of a plasma discharge (PL).

32. System, preferably according to at least one of the claims, such as according to one of Claims 23 to 31, characterized in that at least three ($2a_1$, $2a_2$, 2b) of the mentioned conducting areas are provided and that associated with them is, in pairs, one generator (8) each according to Claim 23 and/or one current branch according to Claim 24, which are triggered in a time-phased manner via a time-control unit (70).

33. System, preferably according to at least one of the claims, such as according to one of Claims 23 to 32, characterized

in that a gas feed (18) empties into the vacuum receptacle, which feed is connected with a supply of reactive gas.

34. System, preferably according to at least one of the claims, such as according to one of Claims 23 to 33, characterized in that at least two electrodes (60a, 60b) are provided for the generation of a plasma (PL) into vacuum receptacle (3) and that one of the electrodes (60b) is applied to the potential of one of the mentioned conducting areas (62).

35. System, preferably according to at least one of the claims, such as according to one of Claims 23 to 34, characterized in that a charge storage (C_D, 20, C_{D1}) and/or a voltage source (U_E) is connected into the discharge current branch.

36. System, preferably according to at least one of the claims, such as according to one of Claims 23 to 35, characterized in that a measurement device (24; 32; 66) is provided on the control discharge or transfer circuit for the measurement of a signal that is representative of the current in the mentioned branch. /33

37. System, preferably according to at least one of the claims, such as according to Claim 36, characterized in that the output signal of the measurement device is fed back upon a control member or control unit (30; 16, 160; 56; 73) for the control of the controlled discharge or transfer circuit.

38. System, preferably according to at least one of the claims, such as according to Claim 36 or 37, characterized in that the output of the measurement device acts upon a threshold value sensitive unit (26) with preferably adjustable threshold value (W) whose output acts upon a control input (30, R) for the controlled discharge or transfer current branch.

39. System, preferably according to at least one of the claims, such as according to one of Claims 36 to 38, characterized in that the output of the measurement device, possibly via an analog/digital converter (34), is fed to an ACTUAL value storage device (36), whose output is supplied together with the output from a REQUIRED value storage device (40) to a comparator unit (38), and that the output of the comparator unit (38), possibly via an analysis unit (42), acts upon a control input for the controlled discharge or transfer current branch.

40. System, preferably according to at least one of the claims, such as according to one of Claims 23 to 39, characterized in that a controlled or controllable charge source (20, 22, 44; 58; C_{D1}) acts upon the section between the two conducting areas (2a, 2b), in particular, during time intervals during which the controlled discharge or transfer

current branch is interrupted in a controlled manner or is controlled in a high-ohmic fashion.

41. System, preferably according to at least one of the claims, such as according to one of Claims 23 to 40, characterized in that at least one of the electrically conducting area (2a) has series-connected in front of it a capacitive element (C_{D1}) in the current branch and that means (46, 46a, 58) are provided in order to charge in a controlled manner the section that is series-connected with the capacitive element (C_{D1}) between the conducting areas (2a, 2c) [sic], whereby the capacitive element is positioned parallel to the section when the current branch (S_1) is connected through.

42. System, preferably according to at least one of the claims, such as according to one of Claims 23 to 41, characterized in that at least one of the areas (2a) has series-connected in front of it a capacitive element (C_{D1}) and that, when the current branch is triggered in a high-ohmic manner or when it is interrupted, the section between the two conducting areas (2a, 2b) is series-connected with the capacitive element, and that for this purpose, a voltage source (58) is positioned in series, which voltage source produces an output signal (dU/dt) that is controlled in terms of time or that changes in a controllable manner in such a way that

a controlled or controllable current flows through the series circuit as a function of the time change of the voltage source output signal.

43. System, preferably according to at least one of the claims, such as according to one of Claims 23 to 42, characterized in that the system is an ion-plating system and that one of the conducting areas (2a) forms carriers for workpieces (1), that via a capacitive element (C_{D1}) and a controlled switching section (S_1), a discharge current branch is formed over the conducting areas (2a, 2b), that the direct-current signal generator (8) is positioned parallel to the switching section (S_1) and that preferably a charge source (58, C_{D1}) works in series with the mentioned section (S_1) and the capacitive element (C_{D1}) or that, with the latter (C_{D1}), a charge source is formed, which charge source is so synchronized with the operation of the switching section (S_1) that, when the switching section (S_1) is interrupted, a predetermined or predeterminable charge current will flow over the section between the two conducting areas (2a, 2b).

44. System, preferably according to at least one of the claims, such as according to Claim 43, characterized in that several of the areas ($2a_x$), acting as workpiece carriers, are provided, that associated with them is one switching section (S_1) each for the formation of a discharge current

branch as well as one capacitive element (C_{D1}) each and preferably one charge source (58, C_{D1}) each or that a charge source is formed with each of the capacitive elements (C_{D1}) and that a time-controlled unit (162, 71) is provided, which triggers the switching sections (S_1) in a time-phased manner.

45. System, preferably according to at least one of the claims, such as according to one of Claims 23 to 44, characterized in that an atomization target object (64) is provided in the system, whereupon there is provided one of the conducting areas (2b) and that the two areas (2a, 2b) are connected by a controlled switching section (S_1) to form a discharge current branch, and that, furthermore, there is provided a direct-current signal generator (8) via a series switching section (S_2), and that, in the process, the switching sections (S_1, S_2) are driven intermittently by a time-controlled unit (160). /34

46. System, preferably according to at least one of the claims, such as according to Claim 45, characterized in that detection means are provided for interference discharges (66) in the receptacle (3) whose output signal is conducted to a comparison unit (70) [sic] to which is supplied the output signal of a REQUIRED value predetermination unit (72) and that the output signal of

the comparison unit (70) acts upon a control unit, preferably a time-controlled unit (16, 160), which triggers the intermittent operation of the switching sections (S_1).

/35

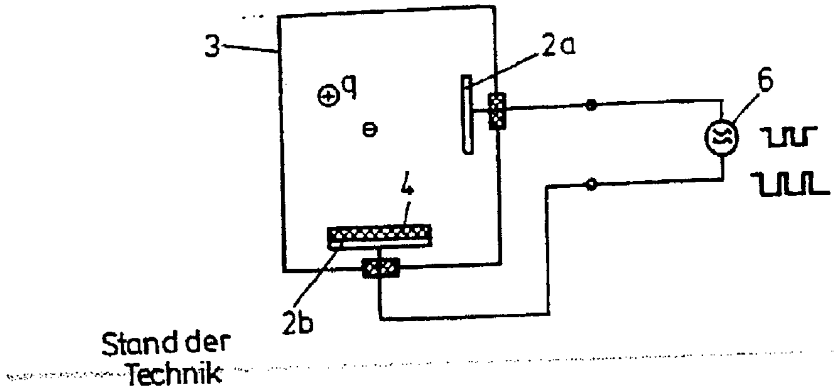


FIG. 1a

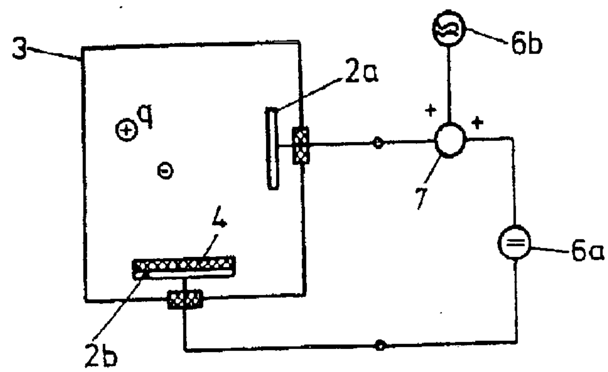


FIG. 1b

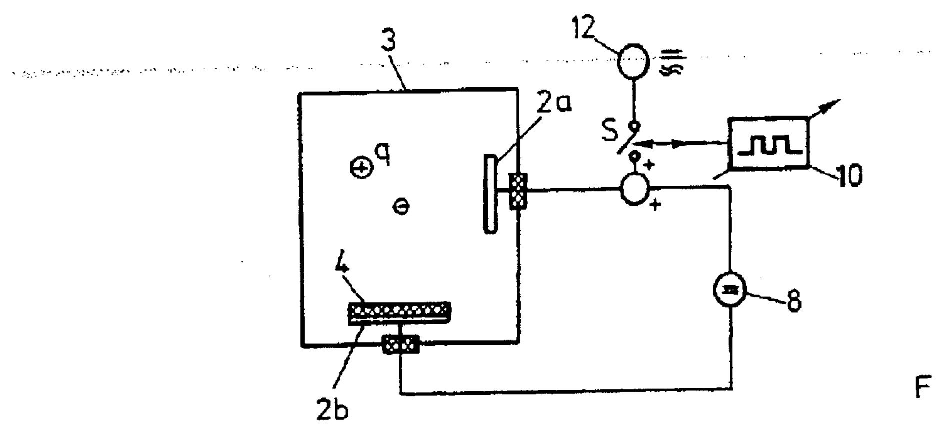


FIG. 2

[Key: 2b = State of the art].

/36

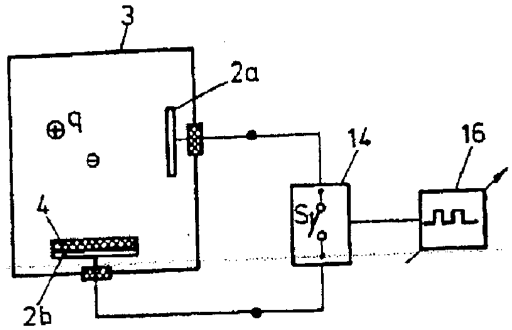


FIG. 3

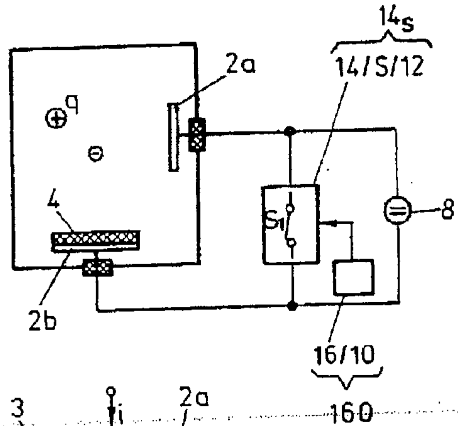
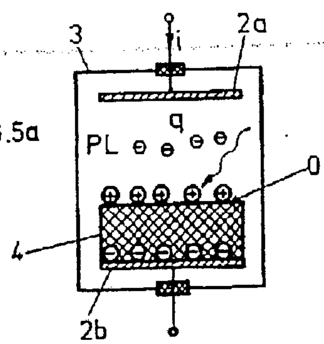


FIG. 4

FIG.5a



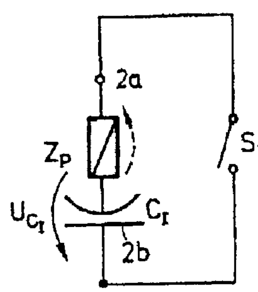


FIG. 5b

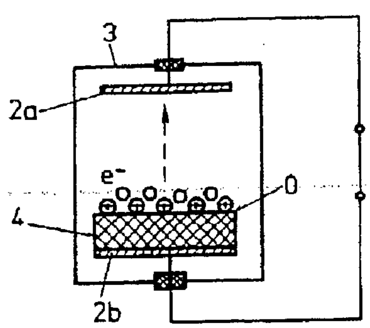


FIG. 5c

/37

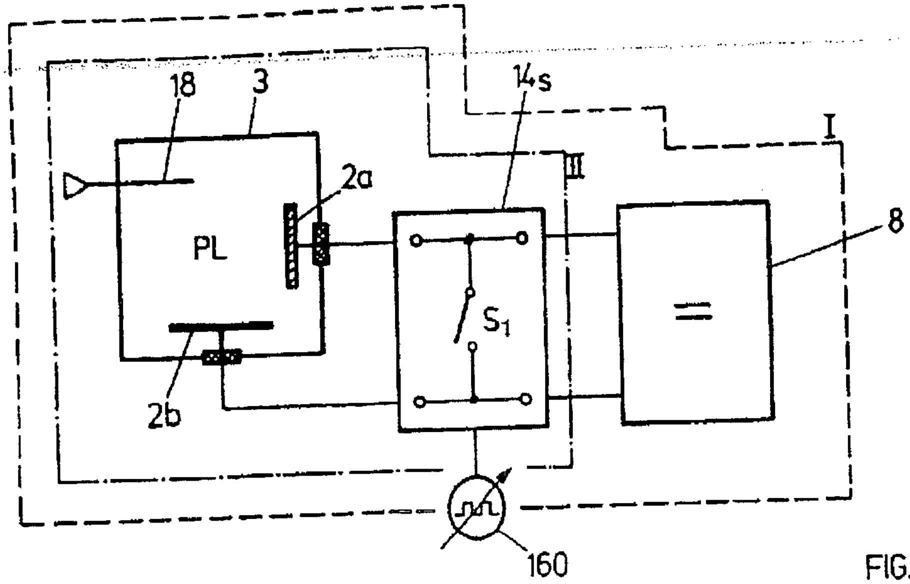


FIG. 6

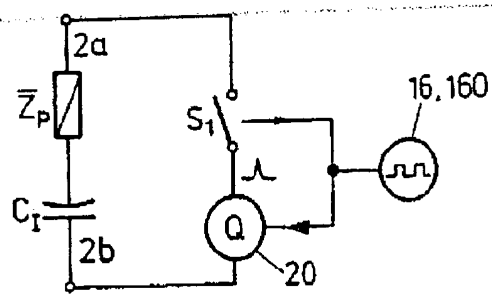
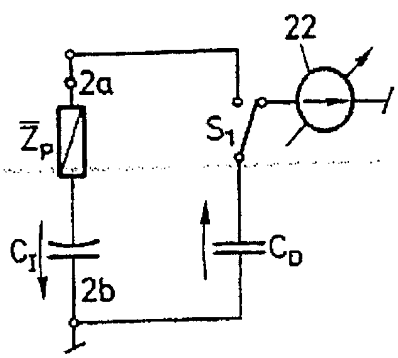


FIG.7a



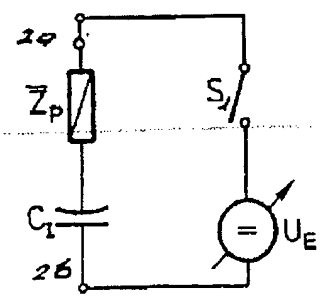
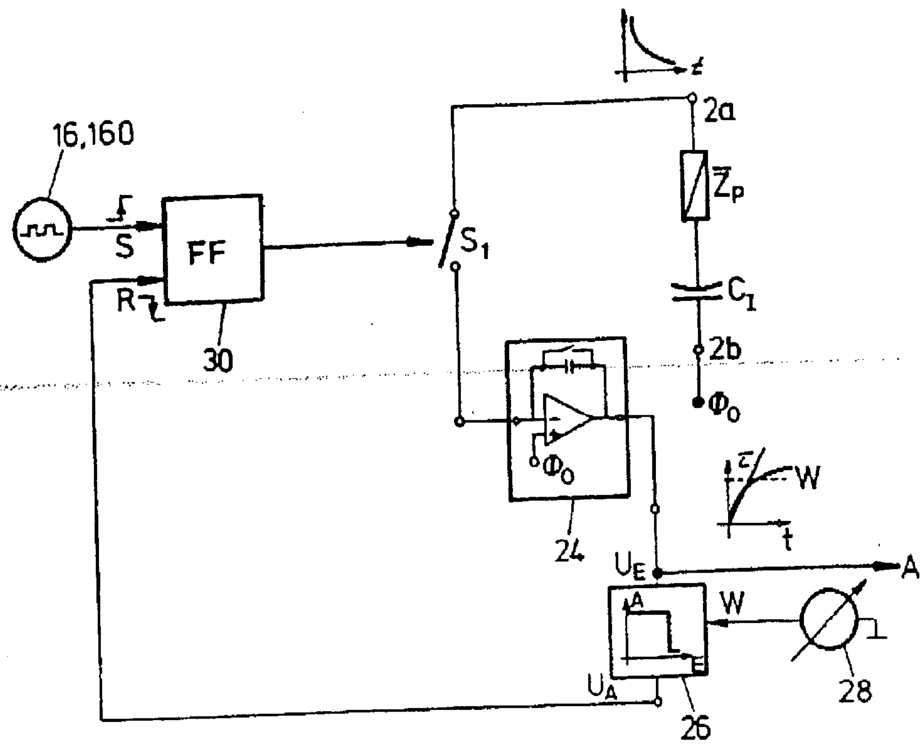


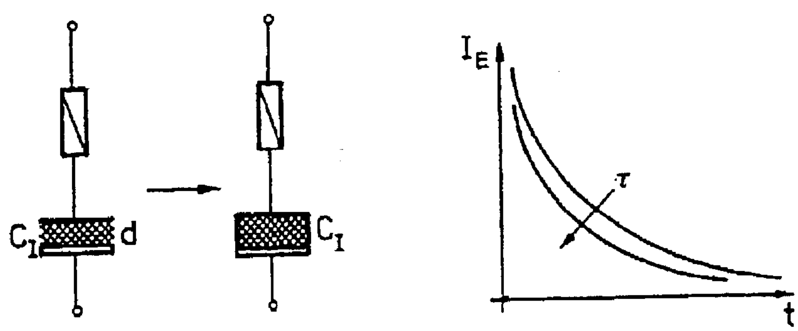
FIG.7b

FIG.7c



16,160
S
R
FF
30
S_1
2a
Z_p
C_I
2b
Φ_0
Φ_0
24
U_E
A
W
t
W
A
E
U_A
26
28

FIG.8



C_I
d
C_I
I_E
τ
t

FIG.9

/39

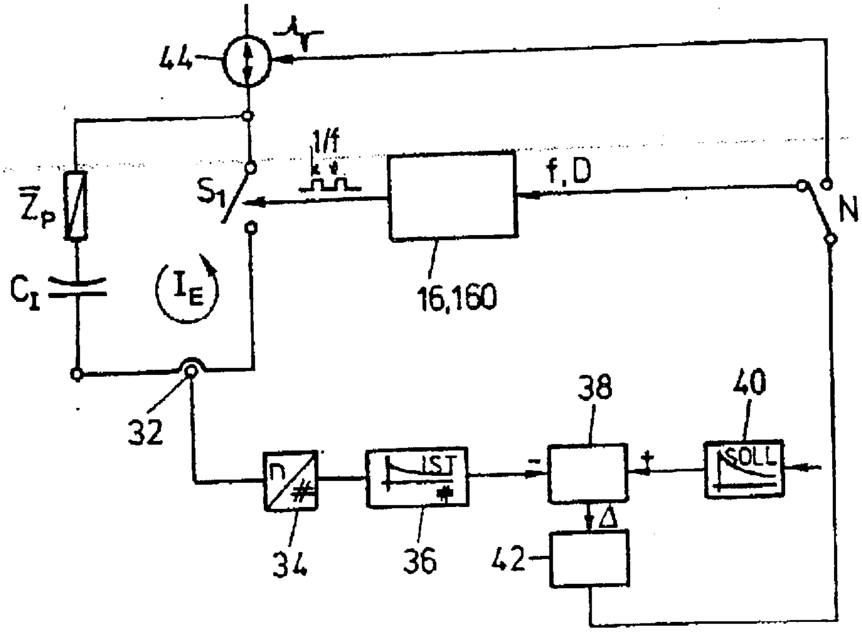
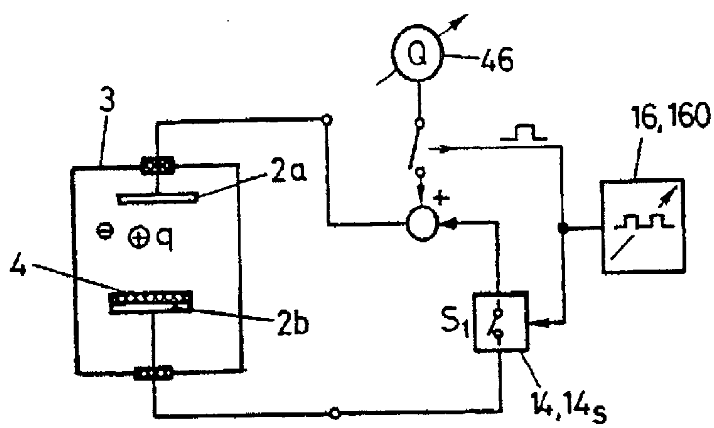

44
1/f
f, D
S_1
N
$\overline{Z}_P$
C_I
I_E
16,160
38
40
32
IST
SOLL
34
36
42

FIG.10


Q
46
3
16,160
2a
⊖ ⊕q
4
2b
S_1
14,14s

/40

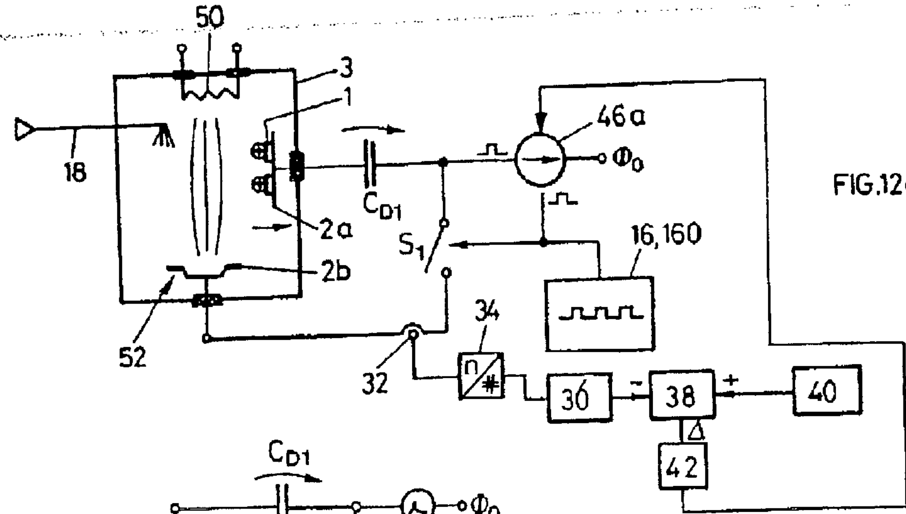


FIG.12a

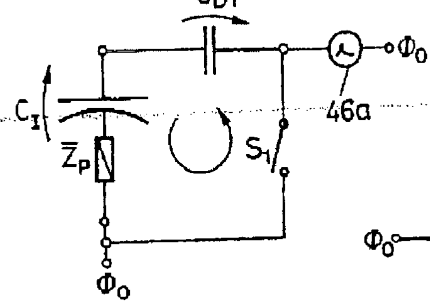


FIG.12c

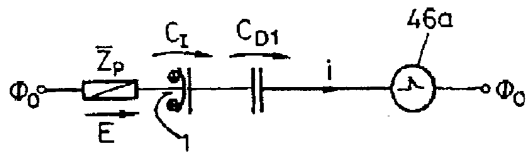


FIG.12b

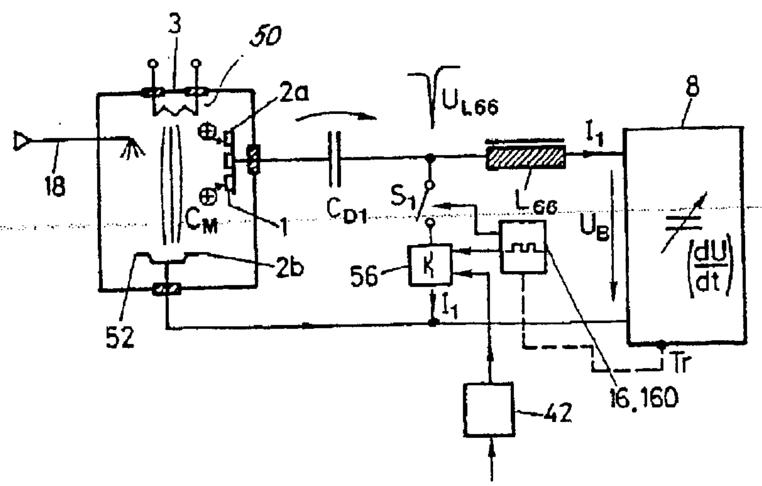


FIG.13

/41

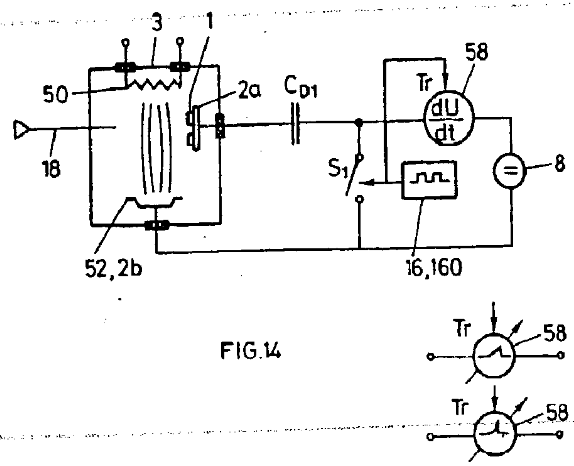


FIG.14

/42

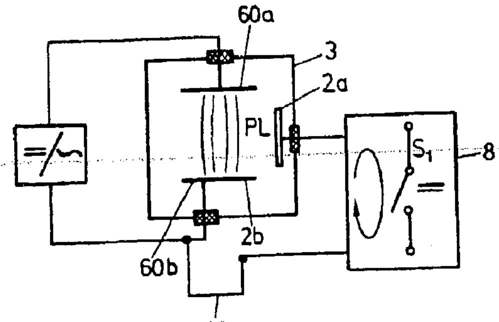


FIG.15

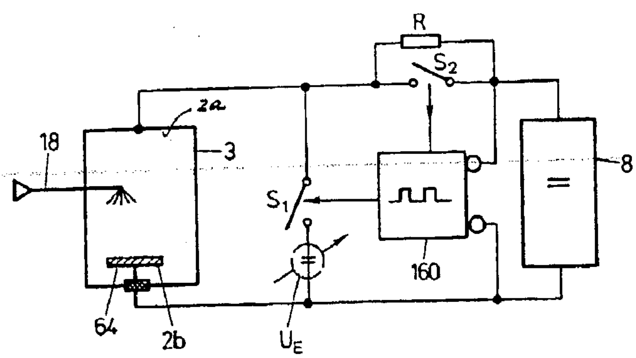


FIG.16

/43

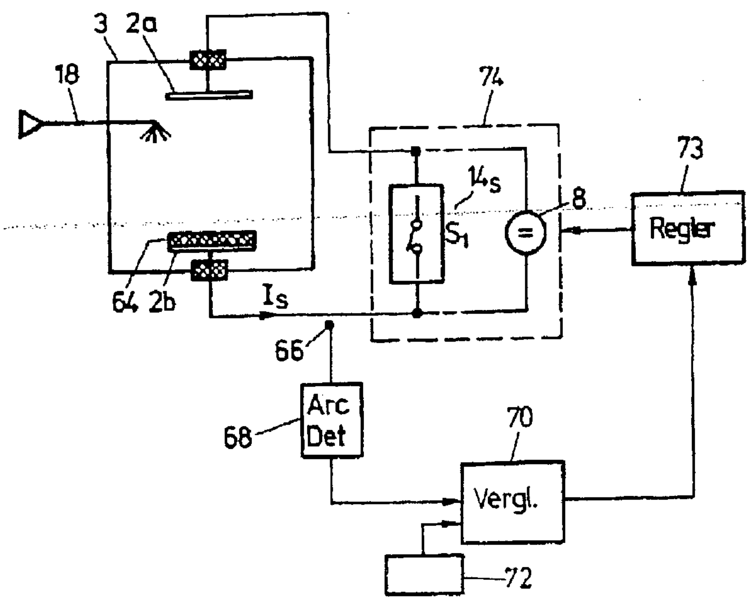


FIG.17

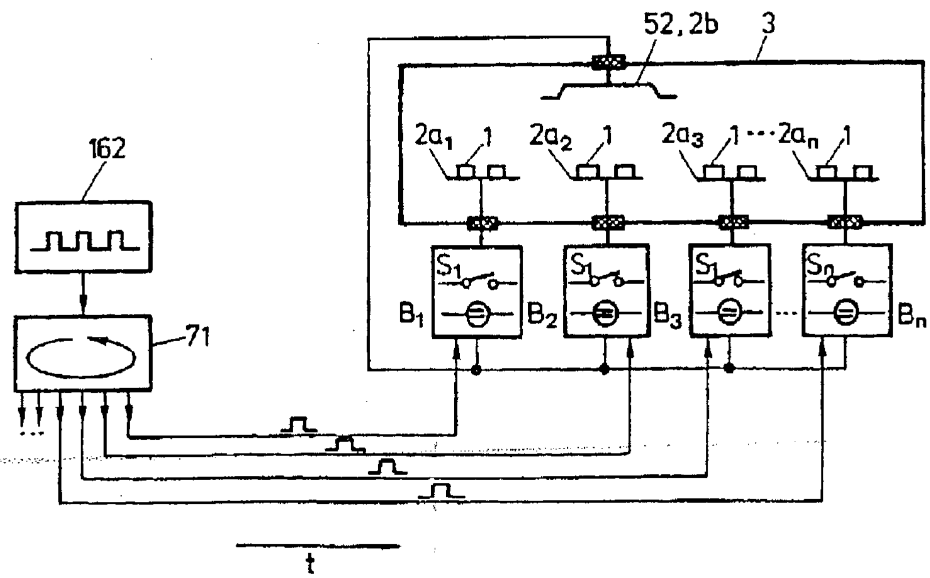


FIG.18

[Key: 73 = Regulator; 70 = Comparator [comparison unit]].

/44

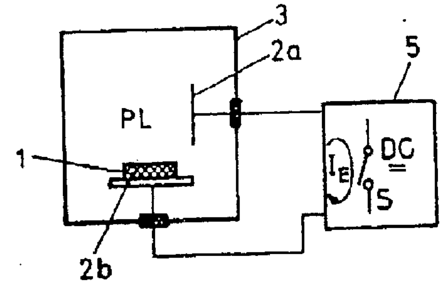
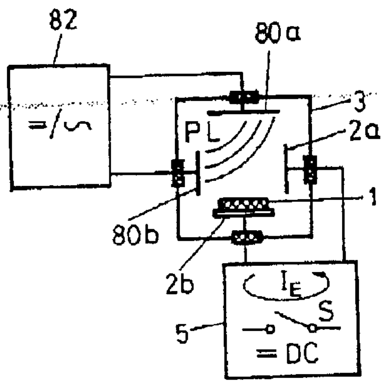
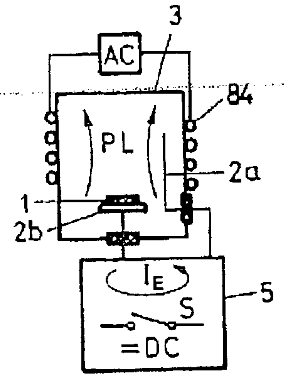


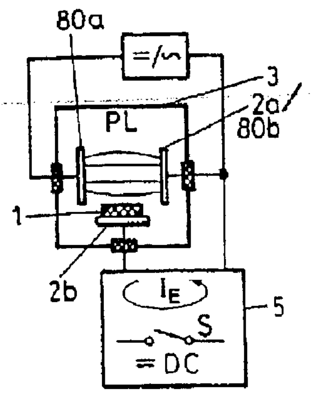
FIG. 19



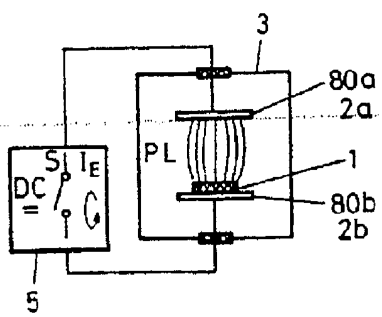
(a)



(b)

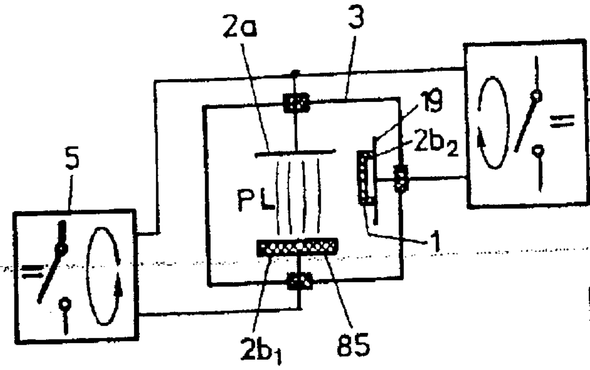


(c)

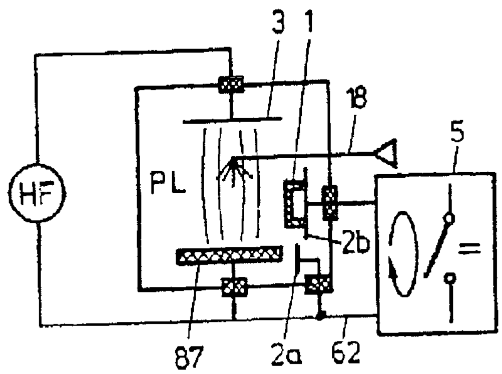


(d)

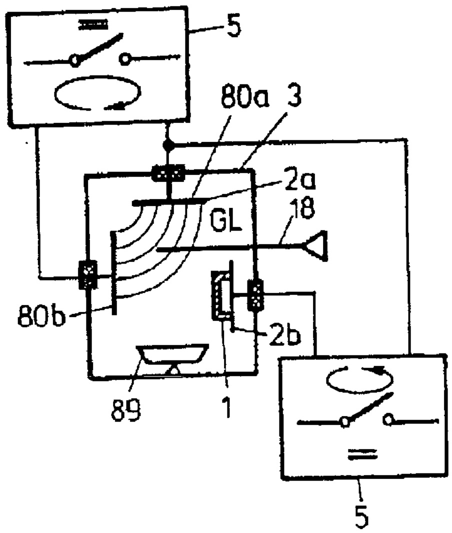
/45


2a
3
5
19
$2b_2$
PL
1
$2b_1$
85

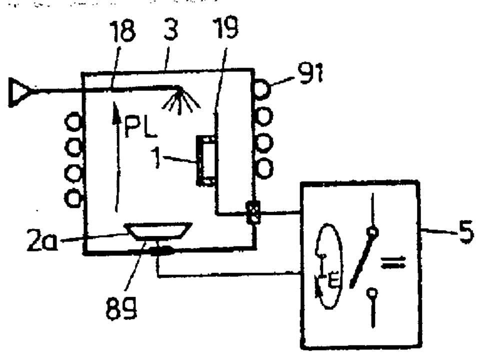
(e)


3
1
18
5
HF
PL
2b
87
2a
62

(f)


5
80a
3
2a
GL
18
80b
2b
89
1

(g)


18
3
19
91
PL
1
2a
89
5

(h)